

November 12, 2021

The Honorable Lopa P. Kolluri  
Principal Deputy Assistant Secretary  
Office of Housing and Federal Housing Administration  
U.S. Department of Housing and Urban Development  
451 Seventh Street, S.W., Room 9100  
Washington, D.C. 20410

Dear Secretary Kolluri:

Pinnacle Actuarial Resources, Inc. (Pinnacle) has completed the final report for the Fiscal Year 2021 Independent Actuarial Review of the Mutual Mortgage Insurance Fund: Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force. The attached report details our estimate of the Cash Flow Net Present Value for Fiscal Year 2021 using data as of September 30, 2021.

Roosevelt C. Mosley, Jr., FCAS, MAAA, CSPA, is responsible for the content and conclusions set forth in the report. I am a Fellow of the Casualty Actuarial Society and a member of the American Academy of Actuaries, and am qualified to render the actuarial opinion contained herein.

It has been a pleasure working with you and your team to complete this study. I am available for any questions or comments you have regarding this report and its conclusions.

Respectfully Submitted,



Roosevelt C. Mosley, Jr. FCAS, MAAA, CSPA  
Principal and Consulting Actuary

Fiscal Year 2021  
Independent Actuarial Review of the  
Mutual Mortgage Insurance Fund:  
Economic Net Worth from Home  
Equity Conversion Mortgage  
Insurance-In-Force

Final Report Based on Data as of September 30, 2021

November 2021



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Commitment Beyond Numbers

# Fiscal Year 2021 Independent Actuarial Review of the Mutual Mortgage Insurance Fund: Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

## Table of Contents

SUMMARY OF FINDINGS.....	1
EXECUTIVE SUMMARY .....	6
IMPACT OF ECONOMIC AND MORTGAGE FACTORS .....	6
DISTRIBUTION AND USE.....	9
RELIANCES AND LIMITATIONS .....	9
SECTION 1. INTRODUCTION .....	11
SCOPE .....	11
HECM BACKGROUND .....	12
Maximum Claim Amount.....	13
Principal Limits and Principal Limit Factors .....	14
Payment Plans .....	14
Unpaid Principal Balance and Mortgage Costs .....	14
Mortgage Terminations.....	15
Assignments and Recoveries .....	15
REPORT STRUCTURE .....	15
SECTION 2. SUMMARY OF FINDINGS.....	17
FISCAL YEAR 2021 NET PRESENT VALUE ESTIMATE.....	17
CHANGE IN ECONOMIC NET WORTH .....	18
SOURCES OF CHANGE FROM THE FISCAL YEAR 2020 REVIEW TO THE FISCAL YEAR 2021 REVIEW ..	19
Update Economic Scenario Forecast.....	19
Update Predictive Models.....	20
Actual Performance of Fiscal Year 2020 to Fiscal Year 2021.....	20
Fiscal Year 2021 Origination Volume.....	20
SECTION 3. CHARACTERISTICS OF HECM FUND ENDORSEMENTS .....	21
VOLUME AND SHARE OF MORTGAGE ORIGINATIONS.....	21

LOAN TYPES.....	22
INTEREST RATE TYPES .....	22
PRODUCT TYPE.....	23
STATE.....	24
MAXIMUM CLAIM AMOUNT .....	25
BORROWER AGE DISTRIBUTION .....	25
BORROWER GENDER .....	26
CASH DRAW DISTRIBUTION .....	27
SECTION 4. CASH FLOW NPV BASED ON ALTERNATIVE SCENARIOS .....	30
BASELINE SCENARIO .....	31
ALTERNATIVE SCENARIO 0 – UPSIDE (4 <sup>TH</sup> PERCENTILE).....	31
ALTERNATIVE SCENARIO 1 – UPSIDE (10 <sup>TH</sup> PERCENTILE) .....	31
ALTERNATIVE SCENARIO 2 – DOWNSIDE (75 <sup>TH</sup> PERCENTILE).....	31
ALTERNATIVE SCENARIO 3 – DOWNSIDE (90 <sup>TH</sup> PERCENTILE).....	31
ALTERNATIVE SCENARIO 4 – DOWNSIDE (96 <sup>TH</sup> PERCENTILE).....	32
SLOWER TREND GROWTH .....	32
STAGFLATION.....	32
NEXT-CYCLE RECESSION .....	32
LOW OIL PRICE .....	33
SUMMARY OF ALTERNATIVE SCENARIOS .....	33
STOCHASTIC SIMULATION .....	33
SENSITIVITY TESTS OF ECONOMIC VARIABLES .....	34
SECTION 5. SUMMARY OF METHODOLOGY .....	37
DATA SOURCES (APPENDIX A) .....	37
DATA PROCESSING – MORTGAGE-LEVEL MODELING.....	38
DATA RECONCILIATION.....	38
HECM BASE TERMINATION MODEL (APPENDIX B).....	40
HECM CASH FLOW DRAW MODELS (APPENDIX C).....	41
HECM CASH FLOW ANALYSIS (APPENDIX E).....	42
Cash Flow Components .....	42

Net Future Cash Flows.....	43
Discount Factors .....	43
LIST OF APPENDICES .....	44
APPENDIX A: DATA SOURCES, PROCESSING AND RECONCILIATION .....	45
DATA SOURCES .....	45
DATA PROCESSING – MORTGAGE-LEVEL MODELING.....	46
DATA RECONCILIATION.....	46
APPENDIX B: HECM BASE TERMINATION MODEL .....	49
MODEL SPECIFICATION .....	49
EXPLANATORY VARIABLES .....	50
MODEL PARAMETERS .....	52
Likelihood of Refinance .....	52
Likelihood of Non-Mortality Termination .....	55
CT2c Claim .....	58
CT2c Sales Price Model.....	59
CT1 Claim Model.....	60
CT1 Sales Price Model.....	62
MODEL VALIDATION .....	63
APPENDIX C: HECM CASH DRAW MODELS.....	68
MODEL SPECIFICATION .....	68
EXPLANATORY VARIABLES .....	69
MODEL PARAMETERS .....	70
Likelihood of Cash Draw .....	70
Likelihood of Full Cash Draw .....	73
Cash Draw Amount Model .....	78
Tax and Insurance Default Frequency Model.....	80
Tax and Insurance Default Amount Model .....	82
MODEL VALIDATION .....	83
APPENDIX D: ECONOMIC SCENARIOS.....	87
ALTERNATIVE SCENARIOS.....	87

GRAPHICAL DEPICTION OF THE SCENARIOS .....	88
STOCHASTIC SIMULATION .....	90
Historical Data .....	91
Modeling Method .....	98
Data Transformation .....	100
Model Specifications .....	100
COVID-19 Pandemic Considerations .....	103
Simulation Generation.....	104
Interest Rate Simulations .....	104
House Price Appreciation Rate (HPA).....	106
Unemployment Rate .....	107
Gross Domestic Product .....	109
Small Business Normalized Optimism Index/ Consumer Confidence Index .....	109
APPENDIX E: HECM CASH FLOW ANALYSIS .....	111
GENERAL APPROACH TO MORTGAGE TERMINATION PROJECTIONS.....	111
CASH FLOW COMPONENTS .....	111
Mortgage Balance.....	112
Tax & Insurance Defaults.....	112
MIP.....	113
Claims.....	114
Note Holding Expenses After Assignment.....	115
Recoveries from Assigned Mortgages .....	115
NET FUTURE CASH FLOWS.....	116
DISCOUNT FACTORS.....	116
APPENDIX F: REVIEW OF HUD ANALYSIS OF ECONOMIC NET WORTH, COMPARISON OF HUD AND PINNACLE MODELS, AND ASSESSMENT OF VULNERABILITIES .....	117
HECM BUDGET MODEL COMMENTARY .....	117
Model Schema .....	118
PINNACLE HECM BUDGET MODEL COMMENTARY .....	120
Model Schema .....	121

Simulation..... 122  
APPENDIX G: SUMMARY OF HISTORICAL AND PROJECTED CLAIM RATES AND LOSS SEVERITIES ..... 123

## SUMMARY OF FINDINGS

This report presents the results of Pinnacle Actuarial Resources, Inc.'s (Pinnacle's) independent actuarial review of the Economic Net Worth associated with Home Equity Conversion Mortgages (HECMs) insured by the Mutual Mortgage Insurance Fund (MMI) for Fiscal Year 2021. The Economic Net Worth associated with Forward mortgages are analyzed separately and are excluded from this report. In the remainder of this report, the term MMI refers to HECMs and excludes Forward mortgages.

Below, we summarize the findings associated with each of the required deliverables.

**Deliverable 1: Produce a written Actuarial Study for HECM that provides the Actuarial Central Estimate of MMI Economic Net Worth as of the end of the subject Fiscal Year and assesses the Department of Housing and Urban Development's (HUD's) estimate of Economic Net Worth.**

The Economic Net Worth is defined as cash available to the MMI plus the Net Present Value (NPV) of all future cash outflows and inflows that are expected to result from the mortgages currently insured by the MMI.

As of the end of Fiscal Year 2021, Pinnacle's Actuarial Central Estimate (ACE) of the MMI HECM Cash Flow NPV is positive \$1.102 billion.

The total capital resource as reported in the Annual Report to Congress Regarding the Status of the FHA Mutual Mortgage Insurance Fund is positive \$3.418 billion at the end of Fiscal Year 2021. Thus, the estimated Economic Net Worth of the MMI is positive \$4.520 billion.

**Deliverable 2: Include a review of the risk characteristics of existing MMI loans including commentary on how such characteristics have changed in recent years.**

A review of the risk characteristics of existing MMI loans and commentary of how these risk characteristics have changed are included in Section 3.

**Deliverable 3: Apply the final HECM actuarial model to the existing portfolio to produce conditional (and cumulative) claim, prepayment, and loss-given-default rates at various levels of aggregation across loans, and for individual policy years and policy year-quarter. Cash-flow summaries should also be provided for major categories (e.g., premium revenues, claim expenses and recoveries or net loss due to claim, with affected loan counts and balances).**

Appendix G shows the interim and final claim rates, non-claim termination rates and loss severities by cohort. Each of these elements is calculated for each year of developed experience, and final projections are also included. Cash flow summaries by major category and credit subsidy cohort are shown below and discussed in more detail in Sections 2 and 4.

Table 1: Projected Cash Flow Summaries

Cash Flow Category	Net Present Value of Cash Flow
Mortgage Insurance Premium	3,651,433,116
Claim Type 1 Loss Incurred	1,618,001,119
Claim Type 2 Loss Incurred	15,668,378,744
Claim Type 2c Recovery	1,677,558,482
Claim Type 2p Recovery	13,465,218,430
Note Holding Expense	405,630,369

**Deliverable 4: To promote transparency of the Study’s assessments, the Study should identify methodological vulnerabilities that may occur in its actuarial models or in HUD’s analyses of Economic Net Worth. This discussion should evaluate the scope and scale of such vulnerabilities in creating possible forecast risk and suggest possible lines of research in these areas. The Study should assess and comment upon HUD’s own models that estimate Economic Net Worth for methodological vulnerabilities and compare HUD’s methodologies with those in the Studies.**

The assumptions and judgments on which the estimates are based are summarized in Section 5. The section titled HECM Base Termination Model (Appendix B) summarizes the specifications and assumptions related to the base termination models. The HECM Cash Flow Draw Projection Models (Appendix C) section summarizes the cash draw models for HECMs with lines of credit. Section 4 discusses the economic assumptions incorporated into the estimates. Lastly, the HECM Cash Flow Analysis (Appendix E) section of Section 5 details the assumptions associated with the cash flow projections. Section 4 also shows the sensitivity of the estimates to alternative economic scenarios.

Section 4 provides a discussion of the economic conditions that could result in material adverse change to the Cash Flow NPV.

Appendix F provides a discussion of the HUD methodologies for estimating Economic Net Worth, a comparison of HUD modeling methodology to those used in this study, and methodological vulnerabilities of the HUD models.

**Deliverable 5: The Studies should include historical data on changes in program terms as well as relevant loan and borrower characteristics (e.g., credit scores, loan-to-value ratios) by cohort and other sub-populations. Loan performance data (claim rates, prepayment rates, severity and recovery rates) both historical and projected should be presented in the “finger-table” formats (arrayed by cohort and policy years for different loan products).**

Section 1 provides historical information on changes in the HECM program terms. A review of the risk characteristics of existing MMI loans and commentary of how these risk characteristics have changed are included in Section 3.

Appendix G shows the interim and final claim rates, non-claim termination rates and loss severities by cohort. Each of these elements is calculated for each year of developed experience, and final projections are also included.

**Deliverable 6: The Contractor should use the President’s Economic Assumptions (provided by HUD’s Office of Risk Management and Regulatory Affairs [ORMRA]) for the actuarial central estimates of the Studies. However, in addition to the central single path economic forecast, the Studies should test alternative economic forecasts for stress-testing and sensitivity analysis to estimate ranges of reasonableness.**

Pinnacle’s ACE of Cash Flow NPV is based on the Economic Assumptions for the 2022 Budget from the Office of Management and Budget (OMB Economic Assumptions). Pinnacle also estimated Cash Flow NPV outcomes based on economic scenarios from Moody’s Analytics (Moody’s). The Cash Flow NPV results based on these scenarios are shown in Table 2.

*Table 2: HECM Cash Flow NPV Based on Alternative Economic Scenarios*

Economic Scenario	Fiscal Year 2021
	Cash Flow NPV
Pinnacle ACE	1,102,199,794
Baseline	711,951,199
Alternative 0 – Upside (4th Percentile)	1,416,418,274
Alternative 1 – Upside (10th Percentile)	853,348,161
Alternative 2 – Downside (75th Percentile)	510,874,923
Alternative 3 – Downside (90th Percentile)	535,464,415
Alternative 4 – Downside (96th Percentile)	-573,298,211
Slower Trend Growth	566,118,304
Stagflation	648,377,360
Next-Cycle Recession	313,037,170
Low Oil Price	649,535,194

The range of results based on Moody’s economic scenarios is negative \$573 million to positive \$1.416 billion.

In addition, Pinnacle has estimated a range of outcomes based on 100 randomly generated stochastic simulations of key economic variables. Based on these simulations, the range of Cash Flow NPV estimates is negative \$2.780 billion to positive \$3.779 billion.

The Cash Flow NPV estimate provided by FHA to be used in the FHA’s Annual Report to Congress is positive \$390 million. Based on Pinnacle’s ACE and range of reasonable estimates, we conclude that the FHA estimate of Cash Flow NPV is reasonable.

Pinnacle’s Cash Flow NPV by cohort is shown below for the largest negative outcome and the largest positive outcome based on the stochastic simulation results.

*Table 3: Range of Reasonable Estimates - HECM Cash Flow NPV*

Cohort	Largest Negative	Largest Positive	Pinnacle ACE
2009	-979,535,559	-106,274,850	-550,316,995
2010	-339,948,394	121,276,900	-140,728,689
2011	-164,887,413	180,008,894	-7,804,178
2012	-144,711,602	175,748,220	5,992,481
2013	-240,615,053	258,679,476	3,255,920
2014	-237,906,807	452,889,290	128,639,846
2015	-160,166,593	611,353,627	323,118,936
2016	-69,280,599	808,811,960	528,810,896
2017	-190,148,066	819,259,574	535,508,587
2018	-103,960,065	128,555,020	58,988,582
2019	12,084,576	37,535,022	37,636,837
2020	-12,522,830	114,787,503	98,129,807
2021	-147,996,036	176,429,810	80,967,764
Total	-2,779,594,441	3,779,060,446	1,102,199,794

Additional details for the Moody’s scenarios and the stochastic simulation can be found in Section 4 and Appendix D.

**Deliverable 7: To provide comparability to HUD estimates of Economic Net Worth, the Contractor shall use Federal Credit Reform Act discounting assumptions and procedures.**

Pinnacle has developed estimates of Economic Net Worth using the Federal Credit Reform Act discounting assumptions.

**Deliverable 8: These Studies should use stochastic or Monte Carlo simulations of future economic conditions including for interest rates and house price appreciation. The objective of these requirements is to illustrate the sensitivity of forecasts to economic uncertainty and other forms of forecast error.**

As described in the results for Deliverable 6, additional economic assumptions were generated using Monte Carlo simulations and Moody's economic scenarios. These results are discussed in further detail in Section 4, and a description of the stochastic simulations is included in Appendix D.

**Deliverable 9: Provide econometric appendices to the Studies that include variable specifications and statistical output from all regressions in the Studies. Individual estimation equations may not be combined for reporting.**

Appendix B shows the predictive model parameters and goodness of fit measures for the Termination model. Appendix C shows the parameters and goodness of fit measures for the Cash Draw models. See the [Model Parameters](#) and [Model Validation](#) sections.

## EXECUTIVE SUMMARY

FHA provides reverse mortgage insurance through the HECM program. HECMs enable senior homeowners to access cash based on the value of their homes. The program began as a pilot program in 1989 and became permanent in 1998. Between 2003 and 2008, the number of HECM endorsements grew because of increasingly widespread product awareness, lower interest rates, higher home values and higher FHA mortgage limits. Prior to Fiscal Year 2009, the HECM program was part of the General Insurance (GI) Fund. The FHA Modernization Act within the Housing and Economic Recovery Act of 2008 (HERA) moved all new HECM program endorsements into the MMI effective October 1, 2008.

The Cranston-Gonzalez National Affordable Housing Act (NAHA), enacted in 1990, introduced a minimum capital requirement for MMI<sup>1</sup>. By 1992, the capital ratio was to be at least 1.25%, and by 2000 the capital ratio was to be no less than 2.0%. The capital ratio is defined by NAHA as the ratio of capital plus Cash Flow NPV to unamortized insurance-in-force (IIF). NAHA also implemented the requirement that an independent actuarial study of the MMI be completed annually. HERA also amended 12 USC 1708(a)-(4) to include the requirement for the annual actuarial study. Accordingly, an actuarial review must be conducted on HECM mortgages within the MMI. In this report, we analyze the HECM portion of the MMI, which is mortgages endorsed in Fiscal Year 2009 and later.

**Pinnacle projects that, as of the end of Fiscal Year 2021, the HECM Cash Flow NPV is positive \$1.102 billion. The total capital resource as reported in the Annual Report to Congress Regarding the Status of the FHA Mutual Mortgage Insurance Fund is positive \$3.418 billion at the end of Fiscal Year 2021. Thus, the estimated Economic Net Worth of the MMI is positive \$4.520 billion.**

To project the Cash Flow NPV, Pinnacle analyzed all HECM historical terminations and associated recoveries using mortgage-level HECM performance data provided by FHA through September 30, 2021. We developed mortgage-level models using various economic and mortgage-specific factors. We then estimated the future mortgage performance of all active mortgages as of the end of Fiscal Year 2021 using various assumptions, including macroeconomic forecasts from OMB, Moody's, and HECM portfolio characteristics.

### Impact of Economic and Mortgage Factors

The projected Cash Flow NPV depends on various economic and mortgage-specific factors. These include the following:

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<sup>1</sup> Public Law 101-625, 101<sup>st</sup> Congress, November 28, 1990, Section 332.

- House Price Index (HPI): HPI reflects the relative change in housing prices from period to period. HPI rates impact the recovery FHA receives upon mortgage terminations and the rate at which borrowers will refinance or move out of their property. HPI projections are obtained from OMB, Moody's scenario projections, and stochastic simulation.
- One-year and 10-year Constant Maturity Treasury (CMT) rates, 1-year London Interbank Offered Rate (LIBOR) and Secured Overnight Financing Rate (SOFR): Interest rates impact the growth rate of mortgage balances and the amount of equity available to borrowers at origination. Interest rate projections used in the cash flow projections are from the OMB projections, Moody's scenario projections, and stochastic simulation. Beginning on May 3, 2021, the LIBOR rate has been discontinued and replaced with the SOFR as an option for adjustable rate HECM loans. This will ultimately apply to both new HECM loans and existing HECM loans with adjustable rates based on LIBOR.
- Mortality Rates: Information on the date of death of borrowers and co-borrowers have either been directly obtained or derived from the U.S. Decennial Life Table for the 1990-1991, 1999-2001, and 2001-2012 populations, published by the Centers for Disease Control and Prevention (CDC) or from the Social Security Administration.
- Cash Drawdown Rates: These rates represent the speed at which borrowers access the equity in their homes over time, which impacts the growth of the mortgage balance. Predictive models have been developed to estimate borrower cash draw rates based on past HECM program experience, borrower characteristics and the economic environment.

The realized Cash Flow NPV will vary from the estimates in this analysis if the actual drivers of mortgage performance deviate from the projections based on the OMB Economic Assumptions. Table 4 presents the Cash Flow NPV from the projections based on the OMB Economic Assumptions and ten scenarios from Moody's. Each scenario estimates the Cash Flow NPV under a specific future path of interest, unemployment and HPI. The range of Cash Flow NPV estimates based on the alternative economic scenarios is negative \$573 million to positive \$1.416 billion.

Table 4: HECM Cash Flow NPV Based on Alternative Economic Scenarios

<b>Economic Scenario</b>	<b>Fiscal Year 2021 Cash Flow NPV</b>
Pinnacle ACE	1,102,199,794
Baseline	711,951,199
Alternative 0 – Upside (4th Percentile)	1,416,418,274
Alternative 1 – Upside (10th Percentile)	853,348,161
Alternative 2 – Downside (75th Percentil	510,874,923
Alternative 3 – Downside (90th Percentil	535,464,415
Alternative 4 – Downside (96th Percentil	-573,298,211
Slower Trend Growth	566,118,304
Stagflation	648,377,360
Next-Cycle Recession	313,037,170
Low Oil Price	649,535,194

The Moody's scenario that produces the highest HECM Cash Flow NPV is the Alternative 0 – Upside (4<sup>th</sup> Percentile). The Alternative 4 – Downside (96<sup>th</sup> Percentile) scenario produces the lowest Cash Flow NPV.

We also randomly generated 100 stochastic simulations of key economic variables. Based on these simulations, the range of Cash Flow NPV estimates is negative \$2.780 billion to positive \$3.779 billion.

## DISTRIBUTION AND USE

This report is being provided to the Federal Housing Administration (FHA) for their use and the use of makers of public policy in evaluating the Cash Flow NPV of the MMI. Permission is hereby granted for its distribution on the condition that the entire report, including the exhibits and appendices, is distributed rather than any excerpt. Pinnacle also acknowledges that excerpts of this report will be used in preparing summary comparisons for FHA's Annual Report to Congress, and permission is granted for this purpose as well. We are available to answer any questions that may arise regarding this report.

Any third parties receiving the report, or excerpts from it, should recognize that the furnishing of this report is not a substitute for their own due diligence and should place no reliance on this report or the data and results contained herein that would result in the creation of any duty or liability by Pinnacle to the third party.

Our conclusions are predicated on a number of assumptions as to future conditions and events. These assumptions, which are documented in this report, must be understood in order to place our conclusions in their appropriate context. In addition, our work is subject to inherent limitations, which are also discussed in this report.

## RELIANCES AND LIMITATIONS

Listed in Section 5 and Appendix A are the data sources Pinnacle has relied on in our analysis. We have relied on the accuracy of these data sources in our calculations. If it is subsequently discovered that the underlying data or information is erroneous or incomplete, then our calculations would need to be revised accordingly.

We have relied on a significant amount of data and information without auditing or verifying the accuracy of the data. This includes economic data projected over the next 79 years from Moody's and OMB. However, we did review as many elements of the data and information as practical for reasonableness and consistency with our knowledge of the mortgage insurance industry. It is possible that the historical data used to develop our estimates may not be predictive of future default and loss experience. We have not anticipated any extraordinary changes to the legal, social or economic environment which might affect the number or cost of mortgage defaults beyond those contemplated in the economic scenarios described in this report. To the extent that realized experience deviates significantly from these assumptions, the actual results may differ, perhaps significantly, from estimated results.

A substantial source of uncertainty relates to the continued emergence of the COVID-19 pandemic. This uncertainty could impact the projection of Cash Flow NPV in several different ways including distortion of historical patterns as the MMI handles claims differently and sudden changes in loan origination exposure as the peril continues to emerge. Some of these uncertainties may affect the settlement of claims that began prior to COVID-19 being declared a pandemic. At this point, it is not possible to reliably forecast these impacts. The COVID-19 pandemic may have a material impact on our Cash Flow NPV estimates as its effects emerge.

The predictive models used in this analysis are based on a theoretical framework and certain assumptions. These models predict the termination rates, cash flow draws and net loss based on a number of individual mortgage characteristics and economic variables. The parameters of the predictive models are estimated over a wide variety of mortgages that originated since 1989 and their performance under the range of economic conditions and mortgage market environments experienced. The models are combined with assumptions about future mortgage endorsements and certain key economic assumptions to produce future projections of the Cash Flow NPV. Although the models are based on mortgages from as far back as 1989, the Cash Flow NPV results presented in the report are only related to mortgages endorsed in Fiscal Year 2009 and later, as this is when the HECM mortgages were added to the MMI.

Pinnacle is not qualified to provide formal legal interpretation of federal legislation or FHA policies and procedures. The elements of this report that require legal interpretation should be recognized as reasonable interpretations of the available statutes, regulations and administrative rules.

## SECTION 1. INTRODUCTION

### Scope

FHA has engaged Pinnacle to perform an annual independent actuarial study of the MMI. This study is required by 12 USC 1708(a)-(4) and must be completed in compliance with the Federal Credit Reform Act as implemented and all applicable Actuarial Standards of Practice (ASOPs).

The FHA Modernization Act within the HERA moved all new endorsements for FHA's HECM program from the GI Fund to the MMI starting in Fiscal Year 2009. Therefore, an actuarial review must also be conducted on the HECM portfolio within the MMI. This report provides the estimated HECM Cash Flow NPV as of September 30, 2021 using data through September 30, 2021.

The MMI is a group of accounts of the federal government which records transactions associated with the FHA's guaranty programs for single family mortgages. Currently, the FHA insures approximately 7.42 million forward mortgages and just over 406,000 HECMs in the MMI.

Per 12 USC 1711-(f), the FHA must ensure that the MMI maintains a capital ratio of not less than 2.0%. The capital ratio is defined as the ratio of capital to MMI obligations on outstanding mortgages (IIF). Capital is defined as cash available to the MMI plus the Cash Flow NPV that is expected to result from the outstanding HECMs insured by the MMI.

The deliverables required for this study are:

1. Produce a written Actuarial Study for HECM that provides the actuarial central estimates (ACEs) of MMI Economic Net Worth as of the end of the subject Fiscal Year and assesses HUD's estimates of Economic Net Worth.
2. Include a review of the risk characteristics of existing MMI loans including commentary on how such characteristics have changed in recent years.
3. Apply the final actuarial HECM model to the HECM part of the MMI portfolio to produce conditional termination rates, timing of assignment, and recovery rates and amounts, by policy year and budget/endorsement year cohort, and by sub-cohort levels defined by policy initiatives and other characteristics.
4. To promote transparency of the Study's assessments, the Study shall identify methodological vulnerabilities that may occur in its actuarial models or in HUD's analyses of Economic Net

Worth. This discussion shall evaluate the scope and scale of such vulnerabilities in creating possible forecast risk and suggest possible lines of research in these areas. The Study shall assess and comment upon HUD's own models that estimate Economic Net Worth for methodological vulnerabilities and compare HUD's methodologies with those in the Study.

5. The Study shall include historical data on changes in program terms as well as relevant loan and borrower characteristics (e.g., credit scores, loan-to-value ratios) by cohort and other sub-populations. Loan performance data (claim rates, prepayment rates, severity and recovery rates) both historical and projected, shall be presented in the "finger-table" formats (arrayed by cohort and policy years for different loan products).
6. The Contractor shall use the President's Economic Assumptions (PEA), provided by the Office of Risk Management and Regulatory Affairs (ORMRA), for the ACEs of the Study. However, in addition to the central single path economic forecast, the Study shall test alternative economic forecasts for stress-testing and sensitivity analysis to estimate ranges of reasonableness.
7. To provide comparability to HUD estimates of Economic Net Worth, the Contractor shall use Federal Credit Reform Act discounting assumptions and procedures.
8. This Study shall use stochastic or Monte Carlo simulations of future economic conditions including for interest rates and house price appreciation. The objective of these requirements is to illustrate the sensitivity of forecasts to economic uncertainty and other forms of forecast error.
9. Provide econometric appendices to the Study that include variable specifications and statistical output from all regressions in the Study. Individual estimation equations shall not be combined for reporting.

### HECM Background

FHA insures reverse mortgages through the HECM program, which enables senior homeowners to borrow against the value of their homes. Since the inception of the HECM program in 1989, FHA has insured over 1.2 million reverse mortgages. The following conditions must be met to be eligible for a HECM:

1. at least one of the homeowners must be 62 years of age or older,

2. if there is an existing mortgage, the outstanding balance must be paid off with the HECM proceeds, and
3. the borrower(s) must have received FHA-approved reverse mortgage counseling to learn about the program.

HECM's are available from FHA-approved lending institutions. These approved institutions provide homeowners with cash payments or lines of credit secured by the collateral property. There is no required repayment as long as the borrowers continue to live in the home and meet FHA guidelines on requirements for paying property taxes and homeowner's insurance premiums and for maintaining the property in a reasonable condition. A HECM terminates for reasons including death, moving out of the home and refinancing. The existence of negative equity does not require borrowers to pay off the mortgage and it does not prevent the borrowers from receiving additional cash draws, if available, based on their HECM contract.

The reverse mortgage insurance provided by FHA through the HECM program protects lenders from losses due to insufficient recovery on terminated mortgages. When a mortgage terminates and the mortgage balance is greater than the net sale price of the home, the lender can file a claim for loss up to the maximum claim amount (MCA). A lender can assign the mortgage note to FHA if the mortgage meets the eligibility requirements when the mortgage balance reaches 98% of the MCA. On assignment, the lender is reimbursed for the balance of the mortgage (up to the MCA). When note assignment occurs, FHA switches from being the insurer to the holder of the note and controls the servicing of the mortgage until termination. At mortgage termination (post-assignment), FHA attempts to recover the mortgage balance including any expenses, accrued interest, property taxes and insurance premiums.

The following are definitions of common HECM terms.

#### Maximum Claim Amount

The MCA is the minimum of the appraised value or purchase price of the home and the FHA mortgage limit at the time of origination. It is the maximum HECM insurance claim a lender can receive. The MCA is also used together with the Principal Limit Factor (PLF) to calculate the maximum amount of initial credit available to the borrower. The MCA is determined at origination and does not change over the life of the mortgage. However, if the home value appreciates over time, borrowers may access additional credit by refinancing. In the event of termination, the entire net sales proceeds can be used to pay off the outstanding mortgage balance, regardless of whether the size of the MCA was capped by the FHA mortgage limit at origination.

## Principal Limits and Principal Limit Factors

FHA manages its insurance risk by limiting the percentage of the initial available equity that a HECM borrower can draw by use of a PLF. The PLF is similar conceptually to the loan-to-value (LTV) ratio applied to a traditional mortgage. For a HECM, the MCA is multiplied by the PLF, which is determined according to the HECM program features and the borrower's age and gender. The result is the maximum HECM Principal Limit (PL) available to be drawn by the applicant. The PLF increases with the borrower's age at HECM origination and decreases as the expected mortgage interest rate increases. Over the course of the mortgage, the PL grows at a rate equal to the sum of the mortgage interest, the Mortgage Insurance Premium (MIP) and the servicing fees. Borrowers can continue to draw cash as long as the mortgage balance is below the current PL (except for the tenure plan, which acts as an annuity)<sup>2</sup>.

## Payment Plans

HECM borrowers access the equity available to them according to the payment plan they select. Borrowers can change their payment plan at any time during the course of the mortgage as long as they have not exhausted their PL. The payment plans are:

- Tenure plan: a fixed monthly cash payment as long as the borrowers stay in their home;
- Term plan: a fixed monthly cash payment over a specified number of years;
- Line of credit: the ability to draw on allowable funds at any time; and
- Any combination of the above.

Under the current program, the initial disbursement period limitation is applicable to all payment plans and subsequent payment plan changes that occur during the initial disbursement period.

## Unpaid Principal Balance and Mortgage Costs

The Unpaid Principal Balance (UPB) is the mortgage balance and represents the amount drawn from the HECM. In general, after the initial cash draw, the mortgage balance continues to grow with additional borrower cash draws and accruals of interest, premiums and servicing fees until the mortgage terminates.

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<sup>2</sup> Mortgagee Letter 97-15, April 24, 1997: Home Equity Conversion Mortgage (HECM) Insurance Program – Implementation of Final Rule and Other Information.

## Mortgage Terminations

When a HECM terminates, the current mortgage balance becomes due. If the net sales proceeds from the home sale exceed the mortgage balance, the borrower or the estate is entitled to the difference. If the net proceeds from the home sale are insufficient to pay off the full outstanding mortgage balance and the lender has not assigned the note, the lender can file a claim for the shortfall, up to the amount of the MCA. HECMs are non-recourse, so the property is the only collateral for the mortgage; no other assets nor the income of the borrowers can be accessed to cover any shortfall.

## Assignments and Recoveries

The assignment option is a unique feature of the HECM program. When the balance of a HECM reaches 98% of the MCA and meets other assignment requirements, the lender can choose to terminate the FHA insurance by redeeming the mortgage note with FHA at face value, a transaction referred to as mortgage assignment. FHA will pay an assignment claim in the full amount of the mortgage balance (up to the MCA) and will continue to hold the note until termination. During the note holding period, the mortgage balance will continue to grow by additional draws and unpaid taxes and insurance. Borrowers can continue to draw cash as long as the mortgage balance is below the current PL. The only exception is that borrowers on the tenure plan are not constrained by the PL. At mortgage termination, the borrowers or their estates are required to repay FHA the minimum of the mortgage balance and the net sales proceeds of the home. These repayments are referred to as post-assignment recoveries.

## Report Structure

The remainder of this report consists of the following sections:

- **Section 2. Summary of Findings** – presents the estimated Economic Net Worth for the HECM portfolio as of the end of Fiscal Year 2021. It also provides a step-by-step analysis of changes from last year’s Review.
- **Section 3. Characteristics of MMI HECMs** – presents various characteristics of HECM endorsements for Fiscal Years 2009 through 2021.
- **Section 4. HECM Cash Flow NPV Based on Alternative Scenarios** – presents the HECM portfolio Cash Flow NPV using alternative economic scenarios.

- **Section 5. Summary of Methodology** – presents an overview of the data processing and reconciliation, base termination models, cash draw models for mortgages with a line of credit and cash flow models used to estimate the Cash Flow NPV.
- **Appendix A: Data: Sources, Processing and Reconciliation** – provides a description of the data sources used for the analysis, the data processing required to prepare the data for analysis and the data reconciliation performed.
- **Appendix B: HECM Base Termination Model** – provides a technical description of the loan performance model for the causes of loan termination.
- **Appendix C: Cash Flow Draw Projection Models** – provides a description of the model to project the cash draws by period for loans that have a line of credit.
- **Appendix D: Economic Scenarios** – describes the forecast of future values of economic factors that affect the performance of the MMI and presents the variation in estimated economic value based on the additional economic scenarios. We also outline the details of the stochastic simulation.
- **Appendix E: HECM Cash Flow Analysis** – provides a technical description of the cash flow model covering the various sources of cash inflows and outflows that HECMs generate.
- **Appendix F: Review of HUD Analysis of Economic Net Worth, Comparison of HUD and Pinnacle Models, and Assessment of Vulnerabilities** – high-level review of HUD models developed to project Economic Net Worth, comparison of the models developed by HUD with the models developed by Pinnacle, and assessment of the vulnerabilities of the models developed.
- **Appendix G: Summary of Historical and Projected Claim Rates, Non-Claim Termination Rates and Loss Severities**

## SECTION 2. SUMMARY OF FINDINGS

This section presents the projected HECM Economic Net Worth for Fiscal Year 2021. This review covers mortgages that were endorsed in Fiscal Year 2009 and subsequent and are still in force as of the end of Fiscal Year 2021. Data through September 30, 2021 was used to estimate the Cash Flow NPV.

### Fiscal Year 2021 Net Present Value Estimate

The Cash Flow NPV of in-force HECMs consists of discounted cash inflows and outflows. HECM cash inflows consist of MIP and recoveries. Cash outflows consist of claims and note-holding expenses. The cash flow model projects cash inflows and outflows using economic forecasts and mortgage performance projections. The Cash Flow NPV is estimated to be positive \$1.102 billion as of the end of Fiscal Year 2021. This estimate is the result of the cash flow projections based on the 2021 OMB Mid-Term Review of the President’s Economic Assumptions.

The total capital resource as reported in the Annual Report to Congress Regarding the Status of the FHA Mutual Mortgage Insurance Fund is positive \$3.418 billion as of September 30, 2021. Thus, the Actuarial Central Estimate (ACE) of the Economic Net Worth of the MMI is positive \$4.520 billion.

According to Cranston-Gonzalez National Affordable Housing Act (NAHA), IIF is defined as the “obligation on outstanding mortgages.” We calculate the IIF as the total UPB of all HECMs remaining in the insurance portfolio as of September 30, 2021. Table 5 shows the Cash Flow NPV and IIF for active HECMs by cohort.

Table 5: Cash Flow NPV and IIF by Cohort

Cohort	Net Present Cash	
	Flow of Future Cash Flows (\$ Millions)	Insurance-In-Force (\$ Millions)
2009	-550	6,282
2010	-141	2,745
2011	-8	2,445
2012	6	1,865
2013	3	2,830
2014	129	4,688
2015	323	5,725
2016	529	5,417
2017	536	6,881
2018	59	5,255
2019	38	3,085
2020	98	6,129
2021	81	9,327
Total	1,102	62,675

The Pinnacle Cash Flow NPV estimate compared to the FHA estimate by cohort is shown below.

Table 6: Comparison of Cash Flow NPV by Cohort

Cohort	Cash Flow NPV		
	Pinnacle	FHA	Difference
2009	-550	-1,133	583
2010	-141	-453	313
2011	-8	-273	265
2012	6	-179	185
2013	3	-212	215
2014	129	49	79
2015	323	329	-6
2016	529	696	-167
2017	536	736	-201
2018	59	310	-251
2019	38	84	-46
2020	98	346	-248
2021	81	91	-10
Total	1,102	390	712

The difference between the Pinnacle and FHA estimate is \$712 million, which is 1.1% of the HECM IIF. The Pinnacle estimates of Cash Flow NPV by cohort are lower than the FHA estimates for cohorts 2015 – 2021, and are higher for the cohorts 2014 and prior.

### Change in Economic Net Worth

Table 7 shows the comparison of our estimate of the Cash Flow NPV, Capital Resources available to HUD, IIF, and estimated Economic Net Worth at the end of Fiscal Year 2020 and the current estimate. The present value of future cash flows of the current book of business is estimated to be positive \$1.102 billion.

Table 7: Estimate of Cash Flow NPV as of the end of Fiscal Year 2021 (\$ in millions)

Item	2020	2021	Dollar Difference	Percent Change
Cash Flow NPV	-329	1,102	1,432	
Capital Resources	1,597	3,418	1,821	114.0%
Economic Net Worth	1,268	4,520	3,253	256.6%
Insurance-In-Force	62,645	62,675	30	0.0%

As seen in Table 7, the estimated Fiscal Year 2021 Cash Flow NPV has increased by \$1.432 billion from the level estimated in Fiscal Year 2020, from negative \$329 million to positive \$1.102 billion. The unamortized IIF increased from \$62.65 billion to \$62.67 billion. The change in the Cash Flow NPV

represents the net impact of several significant factors, which are described in detail in the next section.

Sources of Change from the Fiscal Year 2020 Review to the Fiscal Year 2021 Review

Table 8 provides a summary of the decomposition of changes in the Cash Flow NPV of the MMI as of the end of Fiscal Year 2021 as compared to the Cash Flow NPV in the Fiscal Year 2020 Actuarial Review. The overall net change in the Cash Flow NPV is favorable.

Table 8: Changes in Projected Cash Flow NPV

	Change in NPV	Cash Flow NPV - 9/30/21
<b>Baseline FY2009-FY2020</b>		-329,484,795
Impact of assumption change	1,837,706,852	1,508,222,057
Impact of model change	-655,918,317	852,303,740
Impact of book change	168,928,290	1,021,232,030
<b>FY2009-FY2020</b>	<b>1,350,716,825</b>	
<b>FY2021</b>	<b>80,967,764</b>	<b>1,102,199,794</b>
<b>Cumulative Change</b>	<b>1,431,684,589</b>	

This section describes the sources of change in estimates of Cash Flow NPV between the 2021 Actuarial Review and the 2020 Actuarial Review. Separating out the specific impacts can be done only up to a certain degree of accuracy, because it depends on the order in which the decomposition is done. The interdependency among the various components of the analysis prevents us from identifying and analyzing these as purely independent effects. Given this limitation, this section presents a description of the approximate differences in the Cash Flow NPV from that presented in the Fiscal Year 2020 Actuarial Review by source of change.

Update Economic Scenario Forecast

For this decomposition step, we updated the forecasts for the purchase-only house price index (HPI), and the interest and unemployment rates from 2021 President’s Economic Assumptions (PEA) forecast to the 2022 PEA forecast. In addition to the change in the projected economic forecast, we have also updated the previous projected economic forecasts for the fourth quarter of 2020 through the second quarter of 2021 with actual economic data. The net impact of these changes is an increase of \$1.838 billion in the projected Cash Flow NPV.

### Update Predictive Models

In Fiscal Year 2021, we continued to refine the predictive models to better capture the termination and cash draw behavior of loans in the MMI. We re-estimated the models using updated data and revised variable specifications. For details about these model updates and refinements, refer to Appendices B, C and E.

These model changes led to a decrease in estimated economic value in the Cash Flow NPV of \$656 million.

### Actual Performance of Fiscal Year 2020 to Fiscal Year 2021

The actual performance of the MMI for cohorts 2009 – 2020 realized during Fiscal Year 2021 affects the Cash Flow NPV of the MMI estimate of the in-force portfolio. The actual experience for this period was \$169 million better than expected.

### Fiscal Year 2021 Origination Volume

The addition of the origination volume for the Fiscal Year 2021 book of business increased the Cash Flow NPV projection by \$81 million.

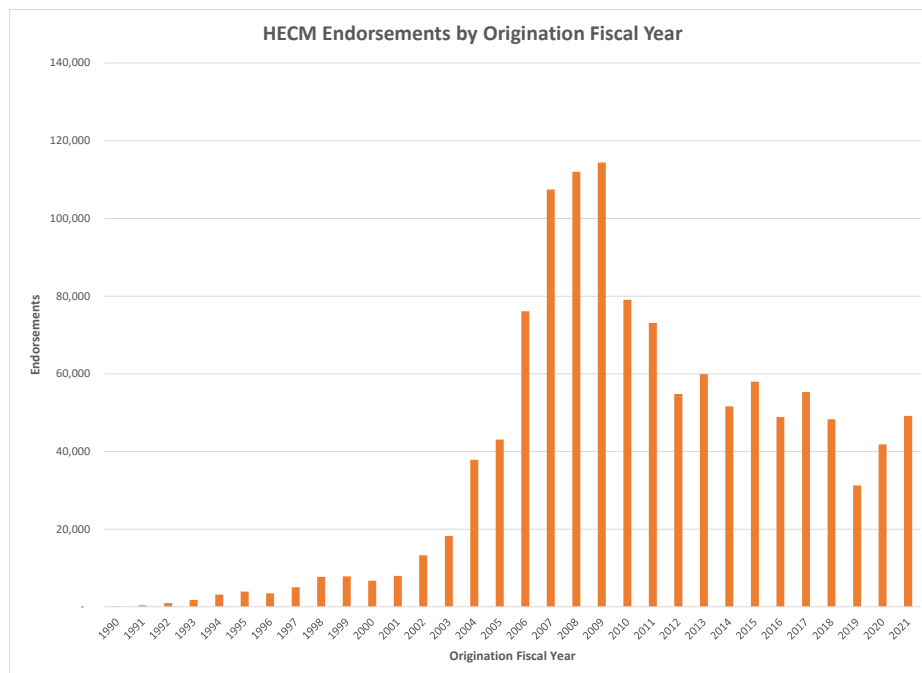
### SECTION 3. CHARACTERISTICS OF HECM FUND ENDORSEMENTS

This section presents the characteristics of the HECM portfolio for the HECM loans endorsed from Fiscal Year 2009 through Fiscal Year 2021. HECM loans were first included in the MMI in Fiscal Year 2009. The loans from these books of business that are still active constitute the HECM Fund portfolio as of the third quarter of Fiscal Year 2021. A review of the characteristics of these cohorts helps define the current risk profile of the HECM Fund. Some of the characteristics of previous books are shown as well to demonstrate trends.

#### Volume and Share of Mortgage Originations

FHA endorsed 49,163 HECM loans in Fiscal Year 2021, with a total projected MCA of \$21.330 billion. This is a 17.5% increase from Fiscal Year 2020 in the number of loans endorsed, and a 31.0% increase in the MCA of loans endorsed. The total number of endorsements for Fiscal Years 2009 to 2021 was 765,685. The corresponding MCA was \$223.873 billion. Since the inception of the HECM program, this program has been the largest reverse mortgage product in the U.S. market, representing the vast majority of reverse mortgages. Figure 1 presents the count of HECM endorsements by origination Fiscal Year.

Figure 1: Number of HECM Endorsements by Origination Fiscal Year





adjustable LIBOR loans were more popular in Fiscal Year 2014 and 2015; however, in Fiscal Years 2016 – 2021, the annually adjustable LIBOR loans were significantly more popular. This is due, in part, to the fact that in 2014 HUD limited the insurability of fixed interest rate mortgages under the HECM program to mortgages with the Single Disbursement Lump Sum payment option.

Beginning in 2021, the LIBOR rate has being discontinued. As a result, the SOFR will replace the LIBOR as an option for an index for adjustable mortgages. As a result, the percentage of loans using the LIBOR index has decreased to just over 30%.

Table 10: Distribution of HECM Loans by Interest Rate Type

Origination Year	LIBOR Indexed		Treasury Indexed		Fixed
	Annually Adjustable	Monthly Adjustable	Annually Adjustable	Monthly Adjustable	
2009	0.02%	34.61%	0.65%	53.09%	11.63%
2010	0.01%	30.58%	0.01%	0.50%	68.90%
2011	0.01%	31.89%	0.00%	0.06%	68.03%
2012	0.00%	30.46%	0.01%	0.12%	69.41%
2013	0.00%	39.35%	0.00%	0.03%	60.63%
2014	2.40%	78.93%	0.00%	0.00%	18.67%
2015	39.97%	44.26%	0.01%	0.01%	15.75%
2016	75.42%	13.90%	0.04%	0.00%	10.64%
2017	86.13%	3.53%	0.00%	0.00%	10.34%
2018	88.44%	1.42%	0.00%	0.00%	10.14%
2019	93.73%	0.22%	0.00%	0.00%	6.05%
2020	97.97%	0.11%	0.01%	0.00%	1.91%
2021	30.15%	0.48%	3.47%	58.58%	7.32%

### Product Type

Almost all the loans endorsed in Fiscal Years 2009 through 2021 are “traditional” HECMs, where the borrowers had purchased their homes prior to taking out the reverse mortgage. A HECM for Purchase program was introduced in January 2009. This program allows seniors to purchase a new principal residence and obtain a reverse mortgage with a single transaction. However, these HECM for Purchase loans have been a small percentage of HECM endorsements each year as seen in Table 11. The distribution of HECMs for Purchase loans had been increasing slowly from 2009 – 2019, but decreased in Fiscal Years 2020 and 2021. In our analysis, the traditional and for-purchase HECMs are treated the same, as the volume of for-purchase HECMs is small.

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force  
Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Table 11: Distribution of HECM Loans by Product Type

Origination Year	Traditional HECMs	HECMs for Purchase	
		First Month Cash Draw < 90% of Initial Principal Limit	First Month Cash Draw >= 90% of Initial Principal Limit
2009	99.51%	0.07%	0.42%
2010	98.25%	0.14%	1.61%
2011	97.90%	0.04%	2.07%
2012	97.04%	0.06%	2.90%
2013	96.52%	0.07%	3.41%
2014	96.46%	0.05%	3.48%
2015	95.84%	0.13%	4.03%
2016	95.16%	0.36%	4.48%
2017	95.24%	0.37%	4.39%
2018	94.59%	0.38%	5.03%
2019	92.66%	0.51%	6.83%
2020	94.10%	0.43%	5.47%
2021	95.54%	0.29%	4.16%

State

Among all endorsements in Fiscal Years 2014 through 2021, over half were originated in the top 10 states as measured by loan counts. California had the highest endorsement volume every year over this period, while Florida has had the second highest endorsement volume since 2015. The endorsement volume in Arizona has increased from 1.7% in Fiscal Year 2012 to 7.0% in Fiscal Year 2021, and is the third largest state. The endorsement breakdown of the top 10 states is shown in Table 12.

Table 12: Distribution of HECM Loans by State

State	Origination Year												
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
California	13.7%	14.0%	13.5%	12.7%	14.1%	17.5%	20.3%	21.8%	23.7%	22.7%	21.1%	24.7%	26.0%
Florida	13.2%	9.0%	6.8%	6.1%	6.5%	6.9%	8.3%	8.8%	8.7%	8.4%	8.6%	8.4%	8.2%
Arizona	3.1%	2.1%	2.0%	1.7%	2.4%	2.9%	3.2%	3.6%	3.7%	4.0%	4.8%	5.6%	7.0%
Colorado	1.8%	1.8%	1.9%	2.0%	2.1%	2.3%	2.4%	3.7%	5.4%	5.9%	6.0%	7.1%	7.0%
Texas	6.6%	8.0%	9.1%	8.9%	8.6%	7.4%	7.0%	7.6%	7.6%	7.4%	7.4%	6.4%	6.0%
Washington	2.8%	3.0%	2.5%	2.3%	2.3%	2.1%	2.3%	2.7%	3.2%	4.3%	4.0%	4.8%	5.7%
Utah	1.5%	1.3%	1.4%	1.8%	2.0%	1.7%	1.7%	1.8%	1.9%	2.4%	2.8%	3.2%	4.2%
Oregon	2.7%	2.3%	1.8%	1.7%	1.4%	1.4%	1.4%	1.9%	2.4%	2.6%	2.4%	2.8%	2.9%
New York	5.3%	5.9%	5.9%	7.2%	6.4%	5.9%	5.7%	4.8%	4.2%	3.8%	4.0%	2.8%	2.5%
Nevada	0.9%	0.6%	0.6%	0.5%	0.7%	1.0%	1.4%	1.5%	1.7%	1.9%	2.3%	2.3%	2.3%
Total Top 10 States	51.6%	47.9%	45.5%	45.0%	46.2%	49.2%	53.7%	58.2%	62.6%	63.3%	63.4%	68.2%	71.8%

### Maximum Claim Amount

The MCA is the minimum of the FHA HECM loan limit and the appraised value (or, if a HECM for Purchase, the minimum of the purchase price and appraised value, not to exceed the HECM loan limit). It is used as the basis of the initial principal limit determination and as the cap on the potential insurance claim amount. Table 13 shows the distribution of HECM endorsements by the MCA. Approximately 65% of loans endorsed in Fiscal Year 2009 had an MCA of less than or equal to \$300,000, and this percentage increased to approximately 73% by Fiscal Year 2012. Since then, the percentage of endorsements less than \$300,000 has decreased steadily to approximately 32% for Fiscal Year 2021.

The percentage of endorsements with an MCA greater than \$300,000 and less than or equal to \$417,000 dropped from 23.3% in 2009 and had been around 12% - 13% percent for Fiscal Years 2010 through 2014, but has since risen to 21.9% in 2021. The percentage of endorsements with an MCA greater than \$417,000 has increased consistently since 2012, and now is at 46.2%.

*Table 13: Distribution of HECM Loans by MCA*

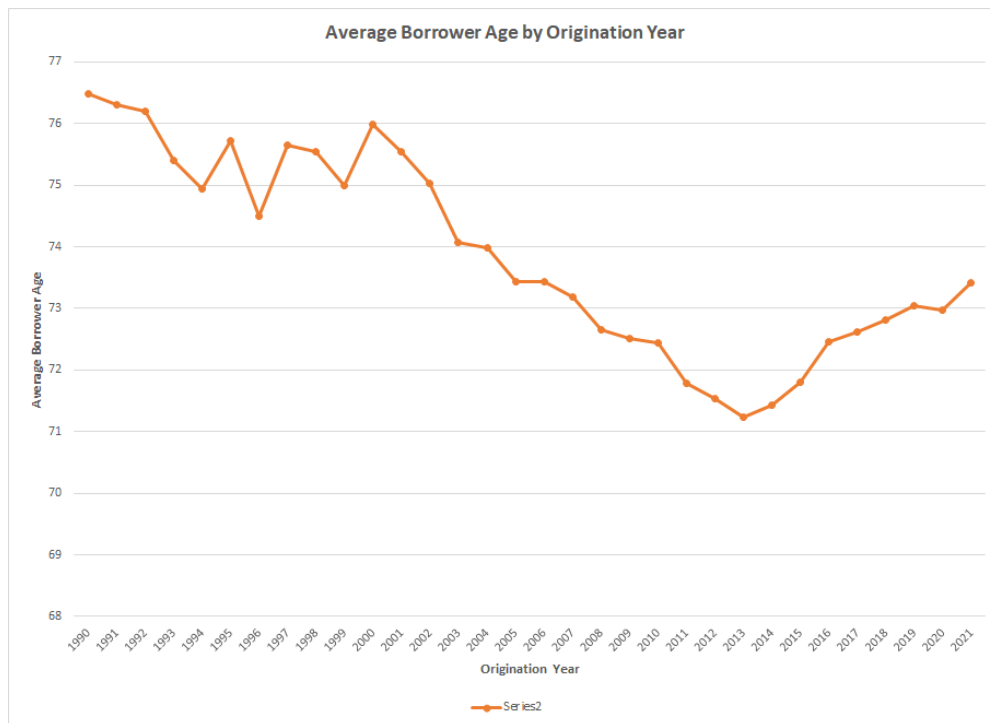
Origination Year	Less Than \$100K	\$100K to \$200K	\$200K to \$300K	\$300K to \$417K	Greater Than \$417K
2009	10.2%	32.4%	22.7%	23.3%	11.3%
2010	12.9%	34.3%	19.9%	12.9%	20.0%
2011	15.7%	35.9%	19.3%	12.0%	17.1%
2012	17.0%	37.0%	18.7%	11.8%	15.5%
2013	16.5%	36.4%	18.7%	12.2%	16.2%
2014	13.7%	34.3%	19.6%	13.2%	19.1%
2015	11.6%	31.7%	20.6%	14.5%	21.6%
2016	8.3%	28.6%	21.8%	16.0%	25.3%
2017	5.9%	25.3%	22.6%	17.8%	28.3%
2018	4.4%	23.2%	23.2%	19.0%	30.3%
2019	3.4%	21.9%	24.2%	19.5%	31.1%
2020	1.8%	16.2%	23.0%	20.7%	38.3%
2021	0.9%	11.5%	19.5%	21.9%	46.2%

### Borrower Age Distribution

The borrower age profile of an endorsement year affects loan termination rates and the PL available to the borrower. Figure 2 shows the average borrower age at origination for Fiscal Years 1990 through 2021. The average borrower age had been declining through 2013, but has been increasing since then. Younger borrowers represent a higher financial risk exposure for FHA as they have a longer life expectancy. The PLFs, which limit the percentage of initial equity available to the borrower, were

lowered for younger borrowers in September 2013, limiting their cash draws to a smaller portion of the equity in the house. This has caused the average borrower age to increase since 2013, and it is now over 73 years old in Fiscal Year 2021.

Figure 2: Average Borrower Age at Origination Year



### Borrower Gender

Gender also affects termination behavior due to differences in mortality rates. HECM loan behavior indicates that single males tend to terminate their loans the quickest, followed by single females, with couples terminating the slowest. Table 14 shows the gender distribution of HECM endorsements. Single females comprised the largest gender cohort of the Fiscal Year 2010 endorsements at 42%, followed by couples at 35%, and single males at 21%. A similar pattern is observed for Fiscal Years 2011 and 2012. In Fiscal Year 2013, couples comprised 39% of HECM loans, surpassing single females to become the largest gender cohort. The single female share is currently 36% while single males remains the lowest at 21%. The concentration in couples rose to 41% in 2016, but has decreased to 38% in 2021. Compared to Fiscal Year 2017, missing genders has increased by almost four percentage points in 2021 to 4.6%.

Table 14: Distribution of HECM Loans by Borrower Gender

Origination				
Year	Male	Female	Couple	Missing
2009	21.69%	40.93%	36.75%	0.63%
2010	21.47%	41.87%	35.25%	1.41%
2011	20.86%	40.25%	37.08%	1.80%
2012	21.22%	39.16%	37.35%	2.27%
2013	21.15%	37.56%	38.96%	2.33%
2014	20.63%	38.74%	38.65%	1.99%
2015	21.86%	38.53%	38.92%	0.69%
2016	21.65%	36.82%	41.05%	0.47%
2017	20.93%	37.14%	40.93%	1.00%
2018	20.70%	36.69%	40.21%	2.39%
2019	21.16%	38.11%	38.81%	1.92%
2020	20.21%	35.29%	39.67%	4.84%
2021	20.78%	35.77%	38.44%	4.57%

### Cash Draw Distribution

Data show that loans which have drawn a higher percentage of the initial amount of equity available tend to have a higher likelihood of refinancing. Table 15 and Table 16 shows the distribution of the cash draw in the first month as a percentage of the initial PL by age group for HECM endorsements.

Younger borrowers tend to draw a higher percentage of the initial amount of equity available than older borrowers. In Fiscal Year 2009, 78% of the 62-65 age group drew over 60% of their initial PL, compared with 54% for the greater-than-85-year-old age group. The incidence of initial draws above 60% of the PL rose sharply to nearly 80% for all age groups combined for Fiscal Years 2010 through 2013. This was mainly driven by the disproportionately high initial draws incurred by most fixed-rate HECMs during that period. In 2014, HUD limited the insurability of fixed interest rate mortgages under the HECM program to mortgages with the Single Disbursement Lump Sum payment option. Also in the same year, HUD introduced a higher MIP charge of 2.50% if the initial draw amount exceeds 60% of the available PL, as compared to the 0.50% MIP rate if the initial draw amount was less than or equal to 60% of the available PL. The overall percentage of loans with a first-month draw over 60% fell from 80% in Fiscal Year 2013 to 48% in Fiscal Year 2019. In Fiscal Year 2021, however, this percentage increased to 66%.

Although younger borrowers typically draw a higher percentage of the initial PL in the first month, the amount of cash drawn represents a smaller percentage of the MCA because the PLF is lower for younger borrowers to account for the risk implied by their longer life expectancy.

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force  
Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Table 15: First-Month Cash Draw as a Percentage of Initial PL (2009 – 2014)

Origination Year	Age Group	Variable Rate Loans			Fixed Rate Loans	
		0-40%	40-60%	60-100%	0-60%	60-100%
2009	62-65	11.76%	9.81%	65.02%	0.19%	13.21%
	66-70	14.14%	10.68%	62.08%	0.09%	13.01%
	71-75	18.64%	11.32%	58.67%	0.01%	11.36%
	76-85	24.66%	11.91%	53.49%	0.03%	9.92%
	86+	36.23%	10.19%	46.06%	0.03%	7.48%
	Total	18.73%	10.93%	58.72%	0.07%	11.54%
2010	62-65	7.35%	4.29%	8.39%	0.19%	79.77%
	66-70	9.07%	5.24%	9.88%	0.13%	75.68%
	71-75	13.29%	6.47%	10.96%	0.12%	69.16%
	76-85	19.95%	7.66%	13.49%	0.10%	58.80%
	86+	32.46%	8.73%	15.04%	0.17%	43.59%
	Total	13.93%	6.14%	11.04%	0.14%	68.75%
2011	62-65	8.37%	5.08%	10.09%	0.25%	76.21%
	66-70	10.60%	5.86%	9.67%	0.17%	73.70%
	71-75	15.15%	6.51%	10.25%	0.13%	67.96%
	76-85	22.49%	8.06%	11.02%	0.13%	58.31%
	86+	36.65%	7.91%	11.15%	0.07%	44.22%
	Total	15.26%	6.42%	10.30%	0.17%	67.86%
2012	62-65	8.58%	5.34%	10.78%	0.14%	75.16%
	66-70	10.83%	5.56%	9.49%	0.10%	74.03%
	71-75	14.18%	6.47%	9.54%	0.07%	69.74%
	76-85	20.68%	7.14%	10.05%	0.13%	62.00%
	86+	33.98%	7.96%	10.15%	0.24%	47.67%
	Total	14.39%	6.16%	10.03%	0.12%	69.30%
2013	62-65	8.13%	5.70%	20.97%	0.32%	64.89%
	66-70	9.69%	5.87%	20.69%	0.32%	63.43%
	71-75	13.43%	6.43%	19.40%	0.35%	60.39%
	76-85	19.35%	7.03%	19.31%	0.28%	54.03%
	86+	31.36%	7.35%	16.56%	0.38%	44.34%
	Total	13.15%	6.25%	20.01%	0.32%	60.27%
2014	62-65	12.26%	26.87%	38.16%	2.02%	20.69%
	66-70	15.15%	25.09%	39.03%	1.94%	18.80%
	71-75	18.81%	25.81%	37.34%	1.94%	16.11%
	76-85	24.68%	26.35%	34.80%	2.11%	12.06%
	86+	36.78%	27.28%	26.61%	2.48%	6.86%
	Total	18.38%	26.10%	36.84%	2.03%	16.65%

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force  
Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Table 16: First-Month Cash Draw as a Percentage of Initial PL (2015 – 2021)

Origination Year	Age Group	Variable Rate Loans			Fixed Rate Loans	
		0-40%	40-60%	60-100%	0-60%	60-100%
2015	62-65	12.71%	38.03%	30.61%	0.67%	17.98%
	66-70	14.58%	35.33%	31.68%	0.60%	17.80%
	71-75	18.03%	34.03%	31.85%	0.55%	15.54%
	76-85	23.60%	35.02%	29.70%	0.66%	11.01%
	86+	33.99%	36.04%	23.29%	1.10%	5.58%
	Total	18.04%	35.71%	30.50%	0.65%	15.10%
2016	62-65	16.76%	36.75%	32.67%	0.81%	13.01%
	66-70	18.02%	33.15%	35.72%	0.49%	12.62%
	71-75	19.10%	32.63%	37.21%	0.25%	10.81%
	76-85	24.21%	33.40%	35.41%	0.40%	6.57%
	86+	34.90%	34.78%	27.02%	0.66%	2.63%
	Total	20.65%	33.96%	34.74%	0.50%	10.15%
2017	62-65	17.78%	34.10%	34.78%	0.98%	12.36%
	66-70	16.75%	30.29%	40.28%	0.47%	12.21%
	71-75	19.07%	28.83%	41.41%	0.43%	10.27%
	76-85	21.88%	30.74%	40.26%	0.40%	6.71%
	86+	32.28%	33.79%	30.81%	0.41%	2.71%
	Total	19.78%	31.06%	38.81%	0.54%	9.81%
2018	62-65	18.40%	33.51%	35.91%	0.69%	11.49%
	66-70	17.12%	29.30%	40.65%	0.53%	12.40%
	71-75	19.86%	28.65%	41.08%	0.31%	10.08%
	76-85	22.05%	31.12%	39.44%	0.42%	6.97%
	86+	32.82%	33.21%	30.63%	0.33%	3.00%
	Total	20.32%	30.69%	38.85%	0.47%	9.67%
2019	62-65	17.81%	32.03%	42.91%	0.41%	6.85%
	66-70	17.19%	29.07%	46.78%	0.20%	6.76%
	71-75	19.87%	28.79%	44.70%	0.18%	6.46%
	76-85	23.93%	31.81%	39.50%	0.31%	4.45%
	86+	33.76%	33.04%	30.50%	0.64%	2.08%
	Total	20.93%	30.55%	42.48%	0.29%	5.75%
2020	62-65	16.29%	26.46%	55.21%	0.10%	1.94%
	66-70	14.30%	24.18%	58.97%	0.09%	2.46%
	71-75	15.33%	23.77%	59.17%	0.09%	1.65%
	76-85	19.02%	26.26%	53.16%	0.17%	1.38%
	86+	30.72%	29.80%	38.33%	0.37%	0.78%
	Total	17.21%	25.38%	55.50%	0.13%	1.78%
2021	62-65	13.21%	25.81%	53.19%	0.46%	7.34%
	66-70	11.51%	20.46%	59.69%	0.44%	7.90%
	71-75	11.23%	18.67%	62.15%	0.33%	7.62%
	76-85	12.91%	19.42%	61.37%	0.38%	5.91%
	86+	24.18%	22.14%	50.05%	0.42%	3.21%
	Total	12.88%	20.59%	59.25%	0.40%	6.88%

## SECTION 4. CASH FLOW NPV BASED ON ALTERNATIVE SCENARIOS

The Cash Flow NPV of the MMI will vary from our estimates if the actual economic drivers of mortgage performance deviate from the baseline projections associated with the OMB Economic Assumptions. In this section, we develop additional estimates of the Cash Flow NPV based on the following approaches:

1. Moody's economic scenarios
2. Stochastic simulation of key economic variables
3. Sensitivity testing of key economic variables

We use these additional estimates of the Cash Flow NPV to develop a range of estimates. These alternative estimates are compared to the Cash Flow NPV resulting from the OMB Economic Assumptions to determine the sensitivity of the Cash Flow NPV estimate to alternative assumptions.

Each Moody's scenario produces an estimate of the Cash Flow NPV using future interest, unemployment and HPI rates as a deterministic path. We are including 10 Moody's scenarios in the analysis. These scenarios are consistent with the scenarios used in the 2020 Actuarial Review.

The Moody's scenarios are:

- Baseline
- Alternative 0 – Upside (4<sup>th</sup> Percentile)
- Alternative 1 – Upside (10<sup>th</sup> Percentile)
- Alternative 2 – Downside (75<sup>th</sup> Percentile)
- Alternative 3 – Downside (90<sup>th</sup> Percentile)
- Alternative 4 – Downside (96<sup>th</sup> Percentile)
- Slower Trend Growth
- Stagflation
- Next-Cycle Recession
- Low Oil Price

The resulting Cash Flow NPV associated with each alternative scenario is summarized in Table 17. Below, we discuss the characteristics of each Moody's scenario.

### Baseline Scenario

In the Baseline scenario, the HPI increases throughout the entire projection period. The rate of increase is about 1.0% per year through 2028, and then increases to about 3.5% per year for the remainder of the projection period. The mortgage interest rate increases through 2027 to about 4.9%, and then levels off near this rate. The unemployment rate is projected to decrease through 2022 to approximately 3.5%, and then increases to 4.7% by 2026. The rate then remains steady at that level for the remainder of the projection period.

### Alternative Scenario 0 – Upside (4<sup>th</sup> Percentile)

In the Alternative Scenario 0 – Upside (4<sup>th</sup> Percentile), the HPI increases throughout the entire projection period. The rate of increase decreases from over 15% to 1.0% by 2024, and then increases to about 3.5% per year for the remainder of the projection period. The mortgage interest rate increases through 2026, then levels off at approximately 4.7% for the remainder of the projection period. The unemployment rate is projected to decrease through 2023 to approximately 2.5%, and then increase gradually until it stabilizes at approximately 4.3%.

### Alternative Scenario 1 – Upside (10<sup>th</sup> Percentile)

In Alternative Scenario 1 – Upside (10<sup>th</sup> Percentile), the HPI is projected to increase throughout the entire projection period. The rate of increases drops sharply from 14.1% per year in the fourth quarter of 2021 to 0.9% per year by the second quarter of 2024. The rate then increases to about 3.5% per year for the remainder of the projection period. The mortgage interest rate increases through 2027, leveling off at approximately 4.9%. The unemployment rate is projected to decrease through 2023 to approximately 3%, and then increases gradually until it stabilizes at approximately 4.1%.

### Alternative Scenario 2 – Downside (75<sup>th</sup> Percentile)

In the Alternative Scenario 2 – Downside (75<sup>th</sup> Percentile), the HPI increases for the entire projection period, but only at a rate of about 1.2% beginning in 2023. The rate of increase then increases to approximately 3.5% by 2033. Mortgage interest rates are projected to increase through 2026, and then level off for the remainder of the projection period at approximately 4.7%. The unemployment rate is projected to increase to 6.6% by the first quarter of 2021, then decrease to just over 4% by 2025.

### Alternative Scenario 3 – Downside (90<sup>th</sup> Percentile)

In the Alternative Scenario 3 – Downside (90<sup>th</sup> Percentile), the HPI increases through the second quarter of 2022, decreases through the first quarter of 2023, and then begins to increase. Mortgage

interest rates flat through the first quarter of 2023, and then begin to increase until they reach a long-term average of about 4.8% in 2028. The unemployment rate increases to 9.0% in the fourth quarter of 2022, then decreases to 4.3% by 2027.

#### Alternative Scenario 4 – Downside (96<sup>th</sup> Percentile)

In Alternative Scenario 4 – Downside (96<sup>th</sup> Percentile), the HPI increases in the fourth quarter of 2021, decreases through the third quarter of 2023, and then begins to increase. Mortgage interest rates are flat through the first of 2022, decrease through the fourth quarter of 2022, and then begin to slowly increase until they reach the long-term average of 5.3% in 2030. The unemployment rate spikes to 10.3% by 2023, and then decreases to 4.4% by 2031.

#### Slower Trend Growth

In the Slower Trend Growth scenario, the HPI increases more slowly than in the Baseline scenario, increasing at a rate of less than 1% from 2023 through 2030. Mortgage interest rates increase for the projection period until they settle at a long-term average of 4.5%. The unemployment rate increases to 5.5% in the second quarter of 2022, then decreases slowly to 4.9% by 2025.

#### Stagflation

In the Stagflation scenario, the HPI increases through the second quarter of 2022, decreases through the third quarter of 2023, and then begins to increase. Mortgage interest rates increase to 4.1% by the first quarter of 2022, and then drop through the first quarter of 2023. Mortgage interest rates then begin to increase to the long-term average of 4.9%. The unemployment rate increases to 8.1% by the third quarter of 2022, and then decreases to a long-term average of 4.4% by 2027.

#### Next-Cycle Recession

In the Next-Cycle Recession scenario, the HPI increases through the fourth quarter of 2023, and then decreases through the third quarter of 2026. The HPI then increases for the remainder of the projection period. The mortgage interest rates increase through the second quarter of 2023, and then decrease through the first quarter of 2025. The rates then settle in at a long-term average of about 4.9%. The unemployment rate decreases to 3.0% by the fourth quarter of 2023, and then increases to 6.4% by the second quarter of 2025. The rate then decreases to 4.1% by 2028, where it remains for the remainder of the projection period.

## Low Oil Price

In the Low Oil Price scenario, the HPI increases throughout the entire projection period, similar to the Baseline scenario. Mortgage interest rates increase through 2027 to a long-term average of to 5.1%. The unemployment rate decreases through the third quarter of 2022, and then increases gradually to a long-term average of 4.4%.

## Summary of Alternative Scenarios

Table 17 shows the projected Cash Flow NPV from the ten deterministic scenarios and Pinnacle's ACE. The range of projected results is between negative \$573 million and positive \$1.416 billion.

Table 17: Cash Flow NPV Summaries from Alternative Scenarios

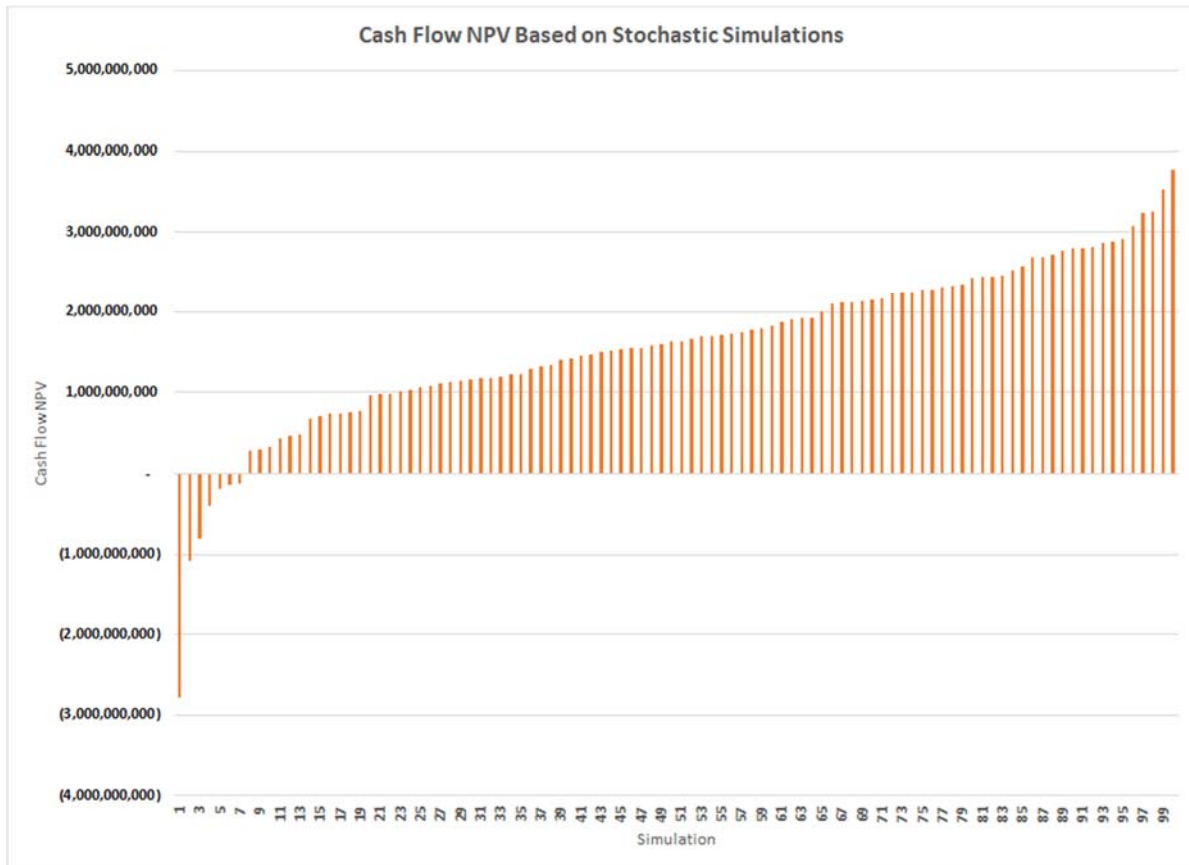
Cohort	Pinnacle ACE	Baseline	Alternative Scenarios									
			Alternative 0 – Upside (4th Percentile)	Alternative 1 – Upside (10th Percentile)	Alternative 2 – Downside (75th Percentile)	Alternative 3 – Downside (90th Percentile)	Alternative 4 – Downside (96th Percentile)	Slower-Trend Growth	Stagflation	Next-Cycle Recession	Low Oil Price	
2009	-550,316,995	-653,681,567	-493,086,548	-599,092,246	-696,894,354	-729,311,297	-874,011,062	-674,039,248	-759,059,663	-716,860,700	-660,024,561	
2010	-140,728,689	-150,287,913	-83,426,921	-129,636,900	-168,345,221	-198,785,956	-278,579,764	-166,509,274	-191,338,157	-179,426,210	-160,584,307	
2011	-7,804,178	-33,146,166	17,204,315	-21,775,379	-38,335,596	-66,417,501	-131,583,029	-47,281,945	-74,437,234	-55,718,548	-36,854,263	
2012	5,992,481	-9,324,439	42,703,728	-265,104	-23,981,056	-34,889,399	-94,941,466	-23,420,770	-32,736,860	-32,986,401	-17,261,354	
2013	3,255,920	-14,698,720	48,956,951	11,391,281	-37,872,168	-48,918,167	-147,794,222	-23,443,039	-55,284,595	-21,537,000	-17,885,515	
2014	128,639,846	94,401,830	172,455,482	118,393,912	64,193,811	68,597,186	-45,778,549	77,817,066	77,335,577	49,646,838	104,785,814	
2015	323,118,936	271,305,798	334,047,805	282,775,518	255,933,817	257,014,371	154,809,624	256,988,296	285,018,262	224,468,026	271,556,804	
2016	528,810,896	501,818,991	547,515,466	507,718,642	500,682,426	524,627,139	404,587,454	490,585,816	584,054,685	452,341,521	501,705,602	
2017	535,508,587	502,815,448	547,468,818	483,103,765	470,609,056	524,808,804	330,677,716	455,398,443	544,559,988	430,131,150	488,811,595	
2018	58,988,582	49,506,615	70,310,875	46,787,418	40,113,731	51,133,752	-11,816,396	38,805,985	60,874,480	37,150,932	49,790,462	
2019	37,636,837	31,949,290	34,612,744	30,983,912	32,893,543	37,791,698	35,287,775	32,068,432	42,067,890	30,511,659	30,799,467	
2020	98,129,807	95,011,063	95,183,481	83,773,970	96,977,519	124,152,077	116,708,575	96,927,871	132,974,641	82,660,465	88,875,046	
2021	80,967,764	26,280,969	82,472,078	39,189,372	14,899,415	25,661,708	-30,864,867	52,220,671	34,348,346	12,655,438	5,820,404	
Total	1,102,199,794	711,951,199	1,416,418,274	853,348,161	510,874,923	535,464,415	-573,298,211	566,118,304	648,377,360	313,037,170	649,535,194	

## Stochastic Simulation

The stochastic simulation approach provides information about the probability distribution of the HECM Cash Flow NPV with respect to different possible future economic conditions and the corresponding terminations, cash flow draws and loss rates. The simulation provides the Cash Flow NPV associated with each one of the 100 possible future economic paths. The distribution of Cash Flow NPV based on these scenarios allows us to gain insights into the sensitivity of the MMI's Cash Flow NPV to different economic conditions.

Figure 3 below shows the range of Cash Flow NPV resulting from the 100 simulated scenarios.

Figure 3: Stochastic Simulation Results



Based on the stochastic simulation results, the range of Cash Flow NPV estimates is negative \$2.780 billion to positive \$3.779 billion. The range of Cash Flow NPV estimates may not include all conceivable outcomes. For example, it would not include extreme events where the contribution of such events to an expected value is not reliably estimable.

The Cash Flow NPV estimate provided by FHA to be used in the FHA’s Annual Report to Congress is positive \$390 million. Based on Pinnacle’s ACE and range of estimates, we conclude that the FHA estimate of Cash Flow NPV is reasonable.

Sensitivity Tests of Economic Variables

The scenario analyses described above were conducted to estimate the distribution of the Cash Flow NPV of the MMI with different possible combinations of economic variable movements in the future. It is also useful to understand the marginal impact of a change in each single economic factor on the Cash Flow NPV. Below, we show the sensitivity of the Cash Flow NPV with respect to the change of a

single economic factor at a time. This sensitivity test is conducted for the House Price Appreciation (HPA) and interest rates.

The marginal impact is measured by the change in Cash Flow NPV based on the OMB Economic Assumption scenario result. These simulations change each of these variables one at a time from the Baseline scenario. The changes are parallel shifts in the path of each variable in the OMB Economic Assumption scenario, where all three interest rates are shifted together and at the same magnitudes, but are kept from going negative.

Figure 4 reports the sensitivity of the Cash Flow NPV with respect to changes in the HPA rate forecast. Specifically, we applied a parallel shift to the annualized HPA rates from the Baseline scenario up and down by 20, 50, 100 and 200 basis points. The sensitivity to shifts in the annualized HPA rates from the Baseline scenario has a positive slope. A negative 100 basis points parallel shift in HPA rate will decrease Cash Flow NPV by \$2.125 billion, and a positive 100 basis points parallel shift in HPA will increase Cash Flow NPV by \$1.715 billion. Figure 5 shows the change in Cash Flow NPV as a percentage of the IIF. The change as a percentage of IIF ranges from -7.3% to +4.8%.

Figure 4 also reports the sensitivity of the Cash Flow NPV with respect to changes in interest rates. Specifically, we applied a parallel shift to the annualized CMT and mortgage rates from the Baseline scenario up and down by 20, 50, 100 and 200 basis points. The sensitivity to shifts in the interest rates from the Baseline scenario has an upward slope. A negative 100 basis points parallel shift in interest rates will increase Cash Flow NPV by \$152 million, and a positive 100 basis points parallel shift in HPA rates will decrease Cash Flow NPV by \$97 million. Figure 5 shows the change in Cash Flow NPV as a percentage of the IIF. The change as a percentage of IIF ranges from -0.2% to +0.4%.

Figure 4: HECM Sensitivity Analysis – Change in Cash Flow NPV

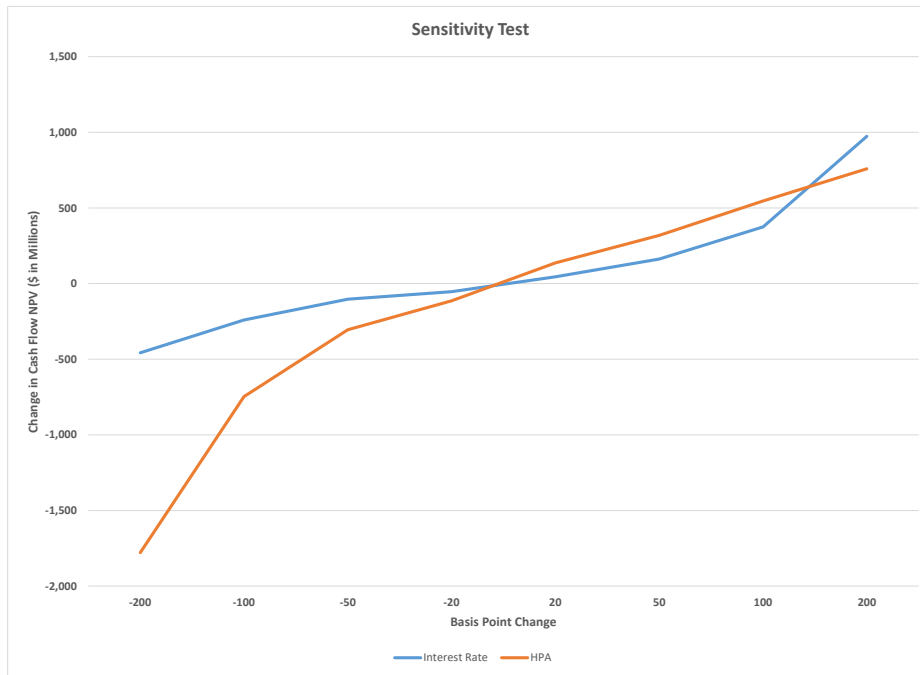
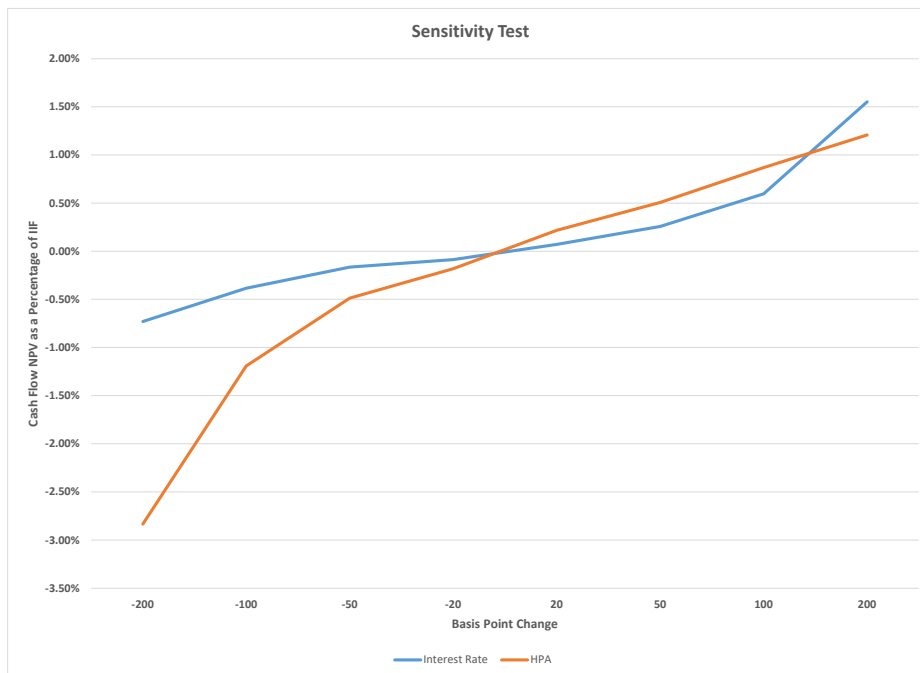


Figure 5: HECM Sensitivity Analysis – Change in Cash Flow NPV as a Percentage of IIF



## SECTION 5. SUMMARY OF METHODOLOGY

This section describes the analytical approach implemented in this analysis.

### Data Sources (Appendix A)

In our analysis, we have relied on data from FHA, Summit-Milliman (S-M), Moody's and OMB.

From FHA and S-M, we have received the following data tables.

1. hermit\_case\_detail: case level data for mortgages
2. hermit\_claim\_detail: data for electronically processed claims
3. hermit\_transactions\_balance: balance transactions data
4. hermit\_transactions\_setaside: setaside transactions data
5. hermit\_transactions\_growth: growth transactions data
6. hermit\_payment\_plan: payment plan information
7. hermit\_lender\_detail: supporting lender information
8. sams\_case\_record: union of sams\_monthly\_record and sams\_archive\_record
9. hecm\_claim\_detail: data for paper claims
10. assigned\_f12\_transactions: historical F12 transaction records for HECM cases that were assigned prior to October 3, 2012
11. idb\_1\_and\_coborr: Integrated Database (IDB) idb\_1\_and\_coborr is a composite of five Single Family legacy systems
12. Consolidated Balance Transfer Files
13. Tmod\_cd\_full: consolidated mortgage-level dataset with information on all cases endorsed to date. The dataset contains variables on mortgage characteristics, borrower characteristics, current mortgage status, and current unpaid principal balance.

From Moody's, we have received the following data elements:

1. Historical Economic Data
2. Baseline Economic Scenario Projections
3. Alternative Economic Scenario Projections

November 12, 2021

From OMB, we have received the Economic Assumptions for the 2021 Budget.

The economic data that is included in the analysis is shown below:

1. HPI
2. CMT rates
3. LIBOR

### Data Processing – Mortgage-Level Modeling

Starting with the raw data, Pinnacle processed the data to create datasets for developing the mortgage-level transition, loss severity and cash draw models. The steps below describe the data processing that occurred to prepare the data that was used for this analysis.

1. Pre-Processing: fields from supplemental tables are added to main HECM case file
2. HECM Quarterly: a number of calculated fields and flags are added to the dataset
3. Transaction Processing: quarterly historical transactions are then processed
4. Claim Processing: historical claim amounts are calculated based on claim transactions
5. UPB: historical quarterly UPB is calculated for each mortgage
6. MIP Processing: initial and subsequent MIP inflows are summarized by case number and period from the Consolidated Balance Transfer Files
7. Cash Draw Processing: incremental and cumulative cash draws are calculated by case number and period
8. Taxes and Insurance Processing: incremental and cumulative taxes and insurance are calculated by case number and period
9. Line of Credit Processing: incremental and cumulative line of credit draws are calculated by case number and period
10. Table Joins: tables generated in steps 3 – 9 are joined to the main table created in step 2

### Data Reconciliation

To reconcile the data processed by Pinnacle with the data provided by FHA, Pinnacle compared summaries of key data elements with the summaries provided by FHA. The summaries for the IIF, number of active assignments and the number of claims to date are shown in the following tables. Most of the data processed matches the FHA data totals with 1%. The exceptions are the insurance in force for 2021 cohort and the number of claims to date for the 2009 and 2010 cohorts. Pinnacle has made HUD aware of these discrepancies and HUD is investigating the differences.

## Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

The reconciliation tables were based on data as of September 30, 2021.

Table 18: Data Validation – Insurance in Force

Credit Subsidy Cohort	Insurance in Force			
	Federal Housing Administration	Independent Actuary	Difference (Actuary - FHA)	Percent Difference (Actuary - FHA) / FHA
2009	6,265	6,266	0.68	0.01%
2010	2,729	2,729	0.48	0.02%
2011	2,437	2,436	-0.63	-0.03%
2012	1,861	1,861	0.25	0.01%
2013	2,823	2,823	0.00	0.00%
2014	4,687	4,687	0.33	0.01%
2015	5,725	5,725	-0.29	-0.01%
2016	5,416	5,415	-0.94	-0.02%
2017	6,882	6,881	-1.75	-0.03%
2018	5,257	5,255	-1.58	-0.03%
2019	3,086	3,085	-0.86	-0.03%
2020	6,132	6,129	-2.22	-0.04%
2021	9,488	9,327	-160.67	-1.69%
Total	62,787	62,619	-167.23	-0.27%
Note:	Sum of UPB where status in ("IIF")			

Table 19: Data Reconciliation - Number of Active Assignments

Credit Subsidy Cohort	Number of Active Assignments			
	Federal Housing Administration	Independent Actuary	Difference (Actuary - FHA)	Percent Difference (Actuary - FHA) / FHA
2009	21,764	21,764	0	0.00%
2010	24,725	24,725	0	0.00%
2011	24,059	24,059	0	0.00%
2012	19,305	19,305	0	0.00%
2013	18,918	18,918	0	0.00%
2014	841	841	0	0.00%
2015	388	388	0	0.00%
2016	231	231	0	0.00%
2017	77	77	0	0.00%
2018	-	-	-	
2019	-	-	-	
2020	-	-	-	
2021	-	-	-	
Total	110,308	110,308		

Table 20: Data Reconciliation – Number of Claims to Date

Credit Subsidy Cohort	Number of Claims to Date			
	Federal Housing Administration	Independent Actuary	Difference (Actuary - FHA)	Percent Difference (Actuary - FHA) / FHA
2009	54,150	51,879	-2271	-4.19%
2010	45,888	45,105	-783	-1.71%
2011	39,203	39,137	-66	-0.17%
2012	28,701	28,708	7	0.02%
2013	26,260	26,265	5	0.02%
2014	2,613	2,613	0	0.00%
2015	1,541	1,541	0	0.00%
2016	692	693	1	0.14%
2017	334	333	-1	-0.30%
2018	50	50	0	0.00%
2019	2	2	0	0.00%
2020	1	-	-1	-100.00%
2021	-	-	-	
Total	199,435	196,326	-3109	-1.56%
Note:	Count of case numbers where clm_typ in (21, 22, 23, 24)			

### HECM Base Termination Model (Appendix B)

Pinnacle developed predictive models to estimate future HECM terminations. No repayment of principal is required on a HECM while the mortgage is active. Termination of a HECM typically occurs due to death of the borrower, the borrower moving out, or voluntary termination via refinance or payoff. The termination model estimates the probabilities of the three mutually exclusive HECM termination events denoted as mortality, mobility and refinance. The modeling approach is as follows:

1. If there is a borrower, we develop two binomial models to determine refinance (“refi” model) or non-mortality termination (“other” model). These models are combined into a single competing hazards probability draw for simulation purposes.
2. If no borrowers are alive going into the period, run-off probabilities are used to determine if the loan terminates. No cash draws or refinances are allowed if there are no borrowers remaining on the loan. If a termination is simulated, then the loan follows the non-mortality termination path described in Step 4.
3. If the loan results in a non-mortality termination, there are two possible paths:
  - a. If the loan is assigned, the “CT2c” model determines the probability the loan ends in conveyance of the property (a CT2c termination) or in repayment of the loan (a CT2p termination).

- b. If the loan is not assigned, the “CT1” incident model determines if the loan results in a Claim Type 1 (a CT1 termination) or no claim (a NCI termination). If it is a CT1, a CT1 sales model determines the sales price of the home relative to UPB which is used in the calculation of the CT1 loss amount.
4. If the loan does not terminate, then we determine if it becomes assigned and/or if any of the borrowers die.

The models incorporate four main categories of explanatory variables:

- Fixed initial borrower characteristics, such as borrower age at origination and gender.
- Fixed initial mortgage characteristics, such as mortgage interest rate, and origination year and quarter.
- Dynamic variables based on mortgage/borrower characteristics, such as mortgage age and borrower and co-borrower ages.
- Dynamic variables derived by combining mortgage characteristics with external macroeconomic data, such as interest rates, HPI, the amount of additional equity available to the borrower through refinancing and the updated ratio of UPB to home value.

### HECM Cash Flow Draw Models (Appendix C)

Over 90% of HECMs have a line of credit associated with them. To estimate the present value of future cash flows on the existing portfolio of HECMs, we need to estimate the future cash draws associated with the line of credit. As these cash draws are not certain, we have developed predictive models to forecast cash draws. We have incorporated the following modeling approach:

1. A binomial model is developed to estimate the likelihood of a cash draw occurring in a period.
2. If a cash draw is simulated, then the next step determines whether it is a full draw of all funds available through the LOC. There are two separate logistic models built for this: 1) A model built only on data from cohorts 2014 and subsequent for the first 8 quarters (“FD8” model), and 2) a model built on all data for quarters 9+ (“FD9+” model). The reason for the split is to account for the first twelve month disbursement period on the funds available for distribution from the LOC.
3. A Generalized Linear Model (GLM) is then developed to estimate the amount of the cash draw for the period if the cash draw is not a full draw.

Using the historical HECM data, for each quarter we develop indicators of whether or not a net positive unscheduled cash draw was taken from the line of credit during that quarter, and also the amount of the cash draw. We then develop models to predict the amount of future cash draws based on a series of explanatory variables.

### HECM Cash Flow Analysis (Appendix E)

HECM termination rates are projected for all future policy years for each active mortgage. The variables used in the projection are derived from mortgage characteristics and economic forecasts. Moody's October 2021 forecasts of interest rates and HPI are combined with the mortgage-level data to simulate the projected economic paths and create the necessary forecasted variables. MSA-level forecasts of HPI apply to mortgages in metropolitan areas; otherwise mortgages use the state-level HPI forecasts. Moody's house price forecasts are generated simultaneously with various macroeconomic variables.

For each mortgage during future policy years, the derived mortgage variables serve as independent variables to the multinomial logistic termination models described in the HECM Base Termination Model section (Appendix B). The termination projections by claim type are then calculated to generate the probability of mortgage termination in a policy quarter by different modes of termination given that it survives to the end of the prior policy quarter. The HECM cash flow model uses these forecasted termination rates to project the cash flows associated with different termination events. Based on the specific characteristics of the mortgage, the probability of each termination is calculated. Then, a random number between 0 and 1 is generated, and based on this random draw a mortgage transition is determined. The projection process continues for each mortgage until the mortgage ends by termination or claim.

### Cash Flow Components

There are four major components of HECM cash flows:

1. MIP
2. claims
3. note holding expenses
4. recoveries on notes in inventory (after assignment)

Premiums consist of upfront and annual MIPs, which are inflows to the HECM program. Recoveries are the property recovery amount received by FHA at the time of note termination after assignment, which is the minimum of the mortgage balance and the predicted net sales proceeds at termination.

The recovery amount for refinance termination is always the mortgage balance. Claim Type 1 payments are cash outflows paid to the lender when the net proceeds of a property sale are insufficient to cover the balance of the mortgage. Claim Type 2 payments result from assignment of mortgages to HUD and note holding payments are additional outflows.

### Net Future Cash Flows

The Cash Flow NPV for the HECM book of business is computed by summing the individual components as they occur over time:

$$\text{Net Cash Flow}_t = \text{Annual Premiums}_t + \text{Recoveries}_t - \text{Claim Type 1}_t - \text{Claim Type 2}_t - \text{Note Holding Expenses}_t$$

### Discount Factors

The discount factors applied were provided by FHA and reflect the most recent U.S. Treasury yield curve, which captures the Federal government's cost of capital in raising funds. These factors reflect the capital market's expectation of the consolidated interest risk of U.S. Treasury securities. Pinnacle has relied on FHA for the discount factors and has not performed an independent analysis of the appropriateness of the discount factors. Our simulations aggregate each future quarter's cash flows, which are treated as being received at the end of the quarter.

## LIST OF APPENDICES

- A. Data: Sources, Processing and Reconciliation
- B. HECM Base Termination Model
- C. HECM Cash Flow Draw Models
- D. Economic Scenarios
- E. HECM Cash Flow Analysis
- F. Review of HUD Analysis of Economic Net Worth, Comparison of HUD and Pinnacle Models, and Assessment of Vulnerabilities
- G. Summary of Historical and Projected Claim Rates and Loss Severities

## APPENDIX A: DATA SOURCES, PROCESSING AND RECONCILIATION

### Data Sources

In our analysis, we have relied on data from FHA, S-M, Moody's and OMB.

From FHA and S-M, we have received the following data tables.

1. hermit\_case\_detail: case level data for mortgages
2. hermit\_claim\_detail: data for electronically processed claims
3. hermit\_transactions\_balance: balance transactions data
4. hermit\_transactions\_setaside: setaside transactions data
5. hermit\_transactions\_growth: growth transactions data
6. hermit\_payment\_plan: payment plan information
7. hermit\_lender\_detail: supporting lender information
8. sams\_case\_record: union of sams\_monthly\_record and sams\_archive\_record
9. hecm\_claim\_detail: data for paper claims
10. assigned\_f12\_transactions: historical F12 transaction records for HECM cases that were assigned prior to October 3, 2012
11. idb\_1\_and\_coborr: Integrated Database (IDB) idb\_1\_and\_coborr is a composite of five Single Family legacy systems
12. Consolidated Balance Transfer Files
13. Tmod\_cd\_full: consolidated mortgage-level dataset with information on all cases endorsed to date. The dataset contains variables on mortgage characteristics, borrower characteristics, current mortgage status, and current unpaid principal balance.

From Moody's, we have received the following data elements:

1. Historical Economic Data
2. Baseline Economic Scenario Projections
3. Alternative Economic Scenario Projections

From OMB, we have received the Economic Assumptions for the 2021 Budget.

The economic data that is included in the analysis is shown below:

1. HPI
2. CMT rates
3. LIBOR

### Data Processing – Mortgage-Level Modeling

Starting with the raw data, Pinnacle processed the data to create datasets for developing the mortgage-level transition, loss severity, and cash draw models. The steps below describe the data processing that occurred to prepare the data that was used for this analysis.

1. Pre-Processing: fields from supplemental tables were added to main HECM case file
2. HECM Quarterly: a number of calculated fields and flags are added to the dataset
3. Transaction Processing: quarterly historical transactions are then processed
4. Claim Processing: historical claim amounts are calculated based on claim transactions
5. UPB: historical quarterly UPB is calculated for each mortgage
6. MIP Processing: initial and subsequent MIP inflows are summarized by case number and period from the Consolidated Balance Transfer Files
7. Cash Draw Processing: incremental and cumulative cash draws are calculated by case number and period
8. Taxes and Insurance Processing: incremental and cumulative taxes and insurance are calculated by case number and period
9. Line of Credit Processing: incremental and cumulative line of credit draws are calculated by case number and period
10. Table Joins: tables generated in steps 3 – 9 are joined to the main table created in step 2

### Data Reconciliation

To reconcile the data processed by Pinnacle with the data provided by FHA, Pinnacle compared summaries of key data elements with the summaries provided by FHA. The summaries for the IIF, number of active assignments and the number of claims to date are shown in the following tables. Most of the data processed by Pinnacle matches the FHA data totals within 1%. The exceptions are the insurance in force for 2021 cohort and the number of claims to date for the 2009 and 2010 cohorts. Pinnacle has made HUD aware of these discrepancies and HUD is investigating the differences.

The reconciliation tables were based on data as of September 30, 2021.

## Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Table 21: Data Validation – Insurance in Force

Credit Subsidy Cohort	Insurance in Force			
	Federal Housing Administration	Independent Actuary	Difference (Actuary - FHA)	Percent Difference (Actuary - FHA) / FHA
2009	6,265	6,266	0.68	0.01%
2010	2,729	2,729	0.48	0.02%
2011	2,437	2,436	-0.63	-0.03%
2012	1,861	1,861	0.25	0.01%
2013	2,823	2,823	0.00	0.00%
2014	4,687	4,687	0.33	0.01%
2015	5,725	5,725	-0.29	-0.01%
2016	5,416	5,415	-0.94	-0.02%
2017	6,882	6,881	-1.75	-0.03%
2018	5,257	5,255	-1.58	-0.03%
2019	3,086	3,085	-0.86	-0.03%
2020	6,132	6,129	-2.22	-0.04%
2021	9,488	9,327	-160.67	-1.69%
Total	62,787	62,619	-167.23	-0.27%
Note:	Sum of UPB where status in ("IIF")			

Table 22: Data Reconciliation - Number of Active Assignments

Credit Subsidy Cohort	Number of Active Assignments			
	Federal Housing Administration	Independent Actuary	Difference (Actuary - FHA)	Percent Difference (Actuary - FHA) / FHA
2009	21,764	21,764	0	0.00%
2010	24,725	24,725	0	0.00%
2011	24,059	24,059	0	0.00%
2012	19,305	19,305	0	0.00%
2013	18,918	18,918	0	0.00%
2014	841	841	0	0.00%
2015	388	388	0	0.00%
2016	231	231	0	0.00%
2017	77	77	0	0.00%
2018	-	-	-	
2019	-	-	-	
2020	-	-	-	
2021	-	-	-	
Total	110,308	110,308		

## Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Table 23: Data Reconciliation – Number of Claims to Date

Credit Subsidy Cohort	Number of Claims to Date			
	Federal Housing Administration	Independent Actuary	Difference (Actuary - FHA)	Percent Difference (Actuary - FHA) / FHA
2009	54,150	51,879	-2271	-4.19%
2010	45,888	45,105	-783	-1.71%
2011	39,203	39,137	-66	-0.17%
2012	28,701	28,708	7	0.02%
2013	26,260	26,265	5	0.02%
2014	2,613	2,613	0	0.00%
2015	1,541	1,541	0	0.00%
2016	692	693	1	0.14%
2017	334	333	-1	-0.30%
2018	50	50	0	0.00%
2019	2	2	0	0.00%
2020	1	-	-1	-100.00%
2021	-	-	-	
Total	199,435	196,326	-3109	-1.56%
Note:	Count of case numbers where clm_typ in (21, 22, 23, 24)			

## APPENDIX B: HECM BASE TERMINATION MODEL

HECM mortgages terminate due to borrower mortality (death), the borrower(s) refinancing the mortgage, or other reasons including the borrower(s) moving out of their home (mobility). A series of binomial logistic models are specified and estimated to capture the mortgage termination behavior.

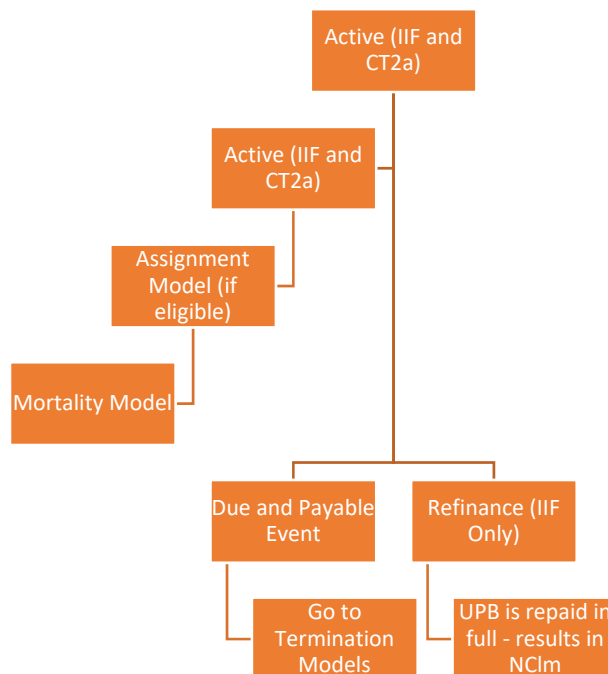
The available FHA historical HECM termination data was used to develop the base termination model. This data includes mortgages that were endorsed under the GI Fund between Fiscal Years 1990 and 2008, and mortgages endorsed under the MMI from Fiscal Year 2009 through March 30, 2021. Only mortgages endorsed under the MMI, however, are used in the calculation of the Cash Flow NPV in this analysis.

### Model Specification

To model the possible transitions, we first specify two binomial models and a mortality run-off model. The binomial models determine the probability of a due and payable event other than mortality and the probability of refinance.

Figure 6 shows the modeling scheme for this structure:

Figure 6: Transition Model Scheme



To model the possible transitions shown above, we incorporate the following approach.

1. If there are borrower(s) alive on the loan going into the period, we develop two binomial models to determine refinance (“refi” model) or non-mortality termination (“othr” model). These models are combined into a single competing hazards probability draw for simulation purposes. If neither a refinance nor a due and payable event is simulated the loan continues.
2. If the loan is not assigned and the UPB has reached 98% of the MCA on the loan we simulate if the loan is assigned. If assignment is simulated the loan moves to “CT2a” status indicating the loan has been assigned but has not yet terminated and a CT2 loss occurs. If the loan is not assigned in the simulation, it continues as “IIF” indicating that the loan is still insured and in-force.
3. At the end of each simulated period we determine if any of the remaining borrowers die based on probabilities derived from mortality tables. If no borrowers remain at the end of the period, the model follows item 4 below in the next period.
4. If no borrowers are alive going into the period, we calculate run-off probabilities that determine if the loan terminates. No cash draws or refinances are allowed if there are no borrowers. If a termination is simulated the loan follows the due and payable termination path described in item 5.
5. If the loan ends up in a due and payable termination, there are two possible paths:
  - a. If the loan is assigned, the “CT2c” model determines the probability the loan ends in conveyance of the property (a CT2c termination) or in repayment of the loan (a CT2p termination)
  - b. If the loan is not assigned, the “CT1” incident model determines if the loan results in a Claim Type 1 (CT1 termination) or no claim (NClm termination). If it is a CT1, a CT1 sales model determines the sales price of the home relative to UPB which is used in the calculation of the CT1 loss amount.

### Explanatory Variables

The following explanatory variables are used in the transition models for assigned and unassigned claims. A general description of the variables is provided below, and more specific detail is included in the Model Parameters section.

- **Min age:** the youngest age amongst the borrower and co-borrowers. This variable is incorporated as a piecewise variate and a grouped categorical variable.

- **Refi var**: refinance incentive - the ratio of the expected gain in principal limit from refinancing to the expected transaction cost. This variable is calculated as  $(MCA_t \times PLF - (init\_MIP_t + orig\_fee_t) - curr\_prncpl\_lmt\_pinni) / (init\_MIP_t + orig\_fee_t)$ . This variable is incorporated as a piecewise variate.
- **Periodnbr**: the number of quarters since the inception of the mortgage. This variable is incorporated as a piecewise variate and a grouped categorical variable.
- **LTV**: ratio of the unpaid principal balance (UPB) to the current principal limit. This variable is incorporated as a piecewise variate.
- **Mob**: home equity ratio - the current indexed property value minus UPB minus the unused principal limit divided by the current indexed property value. This variable is incorporated as a piecewise variate.
- **Delta1yr4q**: change in the one-year CMT rate over the past four quarters. This variable is incorporated as a grouped categorical variable.
- **Delta1yrinit**: change in the one-year CMT rate since loan origination. This variable is incorporated as a grouped categorical variable.
- **Loantyp**: type of HECM loan. Possible values are: 01 – Term, 02 - Line of Credit (LOC), 03 - Tenure; 04 - Term and LOC, 05 - Tenure and LOC, and 06 = Lump Sum. This variable is incorporated as a grouped categorical variable.
- **Gender**: gender of the borrower and co-borrower. Possible values are 1 - Borrower is male and co-borrower information is not available, 2 - borrower is female and the co-borrower information is not available, and 3 - there are two borrowers. This variable is incorporated as a grouped categorical variable.
- **MCA**: maximum claim amount. This variable is incorporated as a piecewise variate.
- **Season**: the quarter of the year. Possible values are 1 – January through March, 2 – April through June, 3 – July through September, and 4 – October through December. This variable is incorporated as a grouped categorical variable.
- **Origfy**: original Fiscal Year. This variable is incorporated as a grouped categorical variable.
- **UPBRatio**: the ratio of the UPB to the current property value. This variable is included as a piecewise variate.
- **Propval**: the indexed property value divided by 10,000. This variable is included as a piecewise variate.
- **Appraisal inflation**: predicted appraisal inflation, which is the percentage by which the original appraisal value reported to HUD is inflated. The appraisal inflation is provided by FHA and Summit-Milliman and is based on additional appraisal information obtained from VEROS. Pinnacle has relied on this appraisal inflation value without independent validation.

For variables that are incorporated as a piecewise variate, further information is provided on how these variates are specified in the [Model Parameters](#) section.

## Model Parameters

### Likelihood of Refinance

The model parameters for the likelihood of refinance are shown below.

Table 24: Model Parameters – Likelihood of Refinance

Variable	ClassVal0	Description	Description Detail	DF	Estimate	StdErr	ProbChiSq
Intercept				1	-8.3846	0.4568	<.0001
vminage_refi_pw2		Variate piecewise min_age	median(0,min_age-64,71-64)	1	0.0180	0.0029	<.0001
vminage_refi_pw3		Variate piecewise min_age	median(0,min_age-71,87-71)	1	0.0079	0.0015	<.0001
vminage_refi_pw4		Variate piecewise min_age	median(0,min_age-87,90-87)	1	-0.0597	0.0132	<.0001
vminage_refi_pw5		Variate piecewise min_age	max(0,min_age-90)	1	-0.0327	0.0122	0.0074
vrefi_refi_pw1		Variate piecewise refi_var <sup>1</sup>	min(max(-17,refi_var),-9)	1	0.0566	0.0089	<.0001
vrefi_refi_pw2		Variate piecewise refi_var <sup>1</sup>	median(0,refi_var+9,-3+9)	1	0.2354	0.0094	<.0001
vrefi_refi_pw3		Variate piecewise refi_var <sup>1</sup>	median(0,refi_var+3,-2+3)	1	0.3828	0.0278	<.0001
vrefi_refi_pw4		Variate piecewise refi_var <sup>1</sup>	median(0,refi_var+2,0+2)	1	0.4749	0.0118	<.0001
vrefi_refi_pw5		Variate piecewise refi_var <sup>1</sup>	max(0,(min(refi_var,18)))	1	0.2329	0.0061	<.0001
vrefi_refi_pw5*vrefi_refi_pw5		Interacted refi_var <sup>1</sup>	max(0,(min(refi_var,18)))	1	-0.0087	0.0004	<.0001
vperiodnbr_REFI_pw1		Variate piecewise period number	min(7,period_number)	1	0.2553	0.0048	<.0001
vperiodnbr_REFI_pw2		Variate piecewise period number	median(0,period_number-7,19-7)	1	-0.0554	0.0017	<.0001
vperiodnbr_REFI_pw3		Variate piecewise period number	median(0,period_number-19,30-19)	1	-0.0716	0.0030	<.0001
vperiodnbr_REFI_pw4		Variate piecewise	median(0,period_number-30,38-30)	1	-0.0425	0.0054	<.0001

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	DF	Estimate	StdErr	ProbChiSq
		period number					
vperiodnbr_REFI_pw5		Variate piecewise period number	median(0,period_number-38,65-38)	1	-0.0230	0.0030	<.0001
mSeason	L01	Categorical Season	mod(period,100) = 1	1	-0.2470	0.0150	<.0001
mSeason	L02	Categorical Season	mod(period,100) = 2	1	-0.2760	0.0141	<.0001
mSeason	L03	Categorical Season	mod(period,100) = 3	1	-0.3114	0.0141	<.0001
mSeason	Z04	Categorical Season	Base level: else		0.0000		
mloantyp_REFI	L01_01	Categorical Loan Type	loan_typ ="01"	1	0.3434	0.0584	<.0001
mloantyp_REFI	L02_05	Categorical Loan Type	loan_typ ="05"	1	0.3528	0.0369	<.0001
mloantyp_REFI	Z03_AO	Categorical Loan Type	Base level: else		0.0000		
vltv_REFI_pw1		Variate piecewise Loan to Value <sup>2</sup>	min(LTV,3)	1	0.3609	0.0994	0.0003
vltv_REFI_pw2		Variate piecewise Loan to Value <sup>2</sup>	median(0,LTV-3,9-3)	1	-0.1229	0.0298	<.0001
vltv_REFI_pw3		Variate piecewise Loan to Value <sup>2</sup>	median(0,LTV-9,60-9)	1	0.0240	0.0010	<.0001
vltv_REFI_pw4		Variate piecewise Loan to Value <sup>2</sup>	median(0,LTV-60,86-60)	1	0.0189	0.0011	<.0001
vltv_REFI_pw5		Variate piecewise Loan to Value <sup>2</sup>	median(0,LTV-86,94-86)	1	0.0465	0.0035	<.0001
vltv_REFI_pw6		Variate piecewise Loan to Value <sup>2</sup>	median(0,LTV-94,99.5-94)	1	0.0224	0.0041	<.0001
vltv_REFI_pw7		Variate piecewise Loan to Value <sup>2</sup>	median(0,LTV-99.5,116-99.5)	1	-0.2297	0.0125	<.0001
vmob_REFI_pw1		Variate piecewise Mobility	median(0,mobility_2,10)	1	-0.0155	0.0065	0.0177
vmob_REFI_pw2		Variate piecewise Mobility	median(0,mobility_2-10,28-10)	1	0.0070	0.0025	0.0056
vmob_REFI_pw3		Variate piecewise Mobility	median(0,mobility_2-28,50-28)	1	0.0110	0.0012	<.0001
mDeltaTy1Init_REFI	L02_3.0	Categorical Change in 1 Year Treasury Rate Initial	Delta_T1Y_Init_p>3	1	0.0883	0.0165	<.0001

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	DF	Estimate	StdErr	ProbChiSq
mDeltaTy1Init_REFI	Z01_Base	Categorical Change in 1 Year Treasury Rate Initial	Base level: else		0.0000		
MGender	L01_M	Categorical Gender	(gender = 1 and borr_alive = 1) or (gender = 3 and coborr_gender_1=1 and coborr_1_alive=1)	1	0.0530	0.0112	<.0001
MGender	Z02_O	Categorical Gender	Base level: else		0.0000		
mAlive	L02_2	Categorical Number Alive	else	1	-0.0959	0.0110	<.0001
mAlive	Z01_1	Categorical Number Alive	Base level: num_alive=1		0.0000		
vdelta_T1Y_4Q_pw1		Variate piecewise Change in 1 Year Treasury Rate 4Q	min(delta_T1Y_4Q,.271)	1	2.5353	0.1268	<.0001
vdelta_T1Y_4Q_pw2		Variate piecewise Change in 1 Year Treasury Rate 4Q	median(0,delta_T1Y_4Q-.271,.44-.271)	1	-8.0384	0.1266	<.0001
vdelta_T1Y_4Q_pw3		Variate piecewise Change in 1 Year Treasury Rate 4Q	median(0,delta_T1Y_4Q-.44,2-.44)	1	0.1814	0.0146	<.0001
vdelta_T1Y_4Q_pw4		Variate piecewise Change in 1 Year Treasury Rate 4Q	median(0,delta_T1Y_4Q-2,2.57-2)	1	0.3834	0.0407	<.0001
vMCA_REFI_pw1		Variate piecewise max_clm_amt	median(0,max_clm_amt/1000,312)	1	0.0034	0.0001	<.0001
vMCA_REFI_pw2		Variate piecewise max_clm_amt	median(0,(max_clm_amt-312000)/1000,495-312)	1	0.0018	0.0001	<.0001
vMCA_REFI_pw3		Variate piecewise max_clm_amt	median(0,(max_clm_amt-495000)/1000,700-495)	1	-0.0013	0.0002	<.0001
vp_appr_infl_REFI_pw1		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1--1,-.06--.1)	1	-48.5438	11.4544	<.0001
vp_appr_infl_REFI_pw2		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1--.06,-.03--.06)	1	-1.4412	4.5630	0.7521
vp_appr_infl_REFI_pw3		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1--.03,-.01--.03)	1	-19.1910	2.7886	<.0001
vp_appr_infl_REFI_pw4		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1--.01,.2--.01)	1	-5.1556	0.1086	<.0001
vp_appr_infl_REFI_pw5		Variate piecewise	median(0,p_appr_infl_1-2,.3-2)	1	2.1420	0.4074	<.0001

Variable	ClassVal0	Description	Description Detail	DF	Estimate	StdErr	ProbChiSq
		Appraisal Inflation					
vp_appr_infl_REFI_pw6		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.3,.4-.3)	1	4.0665	0.7303	<.0001

Likelihood of Non-Mortality Termination

The model parameters for the likelihood of non-mortality termination are shown below.

Table 25: Model Parameters – Likelihood of Non-Mortality Termination

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
Intercept				-5.3653	0.0600	<.0001
vminage_othr_pw1		Variate piecewise Minimum Age	median(0,min_age-72,79-72)	0.1057	0.0053	<.0001
vminage_othr_pw2		Variate piecewise Minimum Age	median(0,min_age-79,91-79)	0.0986	0.0024	<.0001
vminage_othr_pw3		Variate piecewise Minimum Age	max(0,min_age-91)	0.0676	0.0055	<.0001
vmob_othr_pw0		Variate piecewise Mobility	min(0,mobility_2)	0.0048	0.0023	0.0322
vmob_othr_pw1		Variate piecewise Mobility	median(0,mobility_2-0,30-0)	0.0238	0.0011	<.0001
vmob_othr_pw2		Variate piecewise Mobility	max(0,mobility_2-30)	0.0352	0.0006	<.0001
vmob_othr_pw0*vmob_othr_pw0		Interacted Mobility	min(0,mobility_2)	0.0000	0.0000	<.0001
vminage_othr_pw1*vmob_othr_pw0		Interacted piecewise Minimum Age and Mobility	median(0,min_age-72,79-72) and min(0,mobility_2)	0.0015	0.0004	<.0001
vminage_othr_pw2*vmob_othr_pw0		Interacted piecewise Minimum Age and Mobility	median(0,min_age-79,91-79) and min(0,mobility_2)	-0.0009	0.0001	<.0001
vminage_othr_pw1*vmob_othr_pw1		Interacted piecewise Minimum Age and Mobility	median(0,min_age-72,79-72) and median(0,mobility_2-0,30-0)	-0.0010	0.0002	<.0001
vminage_othr_pw2*vmob_othr_pw1		Interacted piecewise Minimum	median(0,min_age-79,91-79) and median(0,mobility_2-0,30-0)	-0.0009	0.0001	<.0001

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
		Age and Mobility				
vminage_othr_pw3*vmob_othr_pw1		Interacted piecewise Minimum Age and Mobility	max(0,min_age-91) and median(0,mobility_2-0,30-0)	-0.0013	0.0003	<.0001
vminage_othr_pw1*vmob_othr_pw2		Interacted piecewise Minimum Age and Mobility	median(0,min_age-72,79-72) and max(0,mobility_2-30)	-0.0025	0.0001	<.0001
vminage_othr_pw2*vmob_othr_pw2		Interacted piecewise Minimum Age and Mobility	median(0,min_age-79,91-79) and max(0,mobility_2-30)	-0.0009	0.0001	<.0001
vmob_othr_pw0*mSeason_othr	L02	Interacted piecewise Mobility and Season	min(0,mobility_2) and mod(period,100) = 2	0.0051	0.0011	<.0001
vmob_othr_pw0*mSeason_othr	L03	Interacted piecewise Mobility and Season	min(0,mobility_2) and mod(period,100) = 3	0.0083	0.0012	<.0001
vmob_othr_pw0*mSeason_othr	Z04	Interacted piecewise Mobility and Season	min(0,mobility_2) and mSeason_othr Base Level	0.0000		
vltv_othr_pw1		Variate piecewise Loan to Value	min(6.5,LTV)	-0.0881	0.0067	<.0001
vltv_othr_pw2		Variate piecewise Loan to Value	median(0,LTV-6.5,88-6.5)	-0.0068	0.0002	<.0001
vltv_othr_pw3		Variate piecewise Loan to Value	median(0,LTV-88,96.5 - 88)	-0.0383	0.0015	<.0001
vltv_othr_pw4		Variate piecewise Loan to Value	median(0,LTV-96.5,102-96.5)	0.1872	0.0028	<.0001
vltv_othr_pw5		Variate piecewise Loan to Value	max(0,LTV-102)	0.0591	0.0019	<.0001
min_age65	L01_62	Categorical Minimum Age	min_age = 62	-0.3917	0.0724	<.0001
min_age65	L02_63	Categorical Minimum Age	min_age = 63	-0.3038	0.0378	<.0001
min_age65	L03_64	Categorical Minimum Age	min_age = 64	-0.2562	0.0299	<.0001
min_age65	L04_65	Categorical Minimum Age	min_age = 65	-0.2106	0.0258	<.0001

## Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
min_age65	L05_72	Categorical Minimum Age	65 < min_age <= 72	-0.0678	0.0129	<.0001
min_age65	Z06_73+	Categorical Minimum Age	Base level: else	0.0000		
mloantyp	L01_01	Categorical Loan Type	loan_typ in ("01","03","04","05","06")	-0.0307	0.0094	0.0010
mloantyp	Z02_02	Categorical Loan Type	Base level: else	0.0000		
MGender	L01_M	Categorical Gender	(gender = 1 and borr_alive = 1) or (gender = 3 and coborr_gender_1=1 and coborr_1_alive=1)	0.0119	0.0063	0.0601
MGender	Z02_O	Categorical Gender	Base level: else	0.0000		
mSeason_othr	L02	Categorical Season	mod(period,100) = 2	0.0462	0.0069	<.0001
mSeason_othr	L03	Categorical Season	mod(period,100) = 3	0.0355	0.0069	<.0001
mSeason_othr	Z04	Categorical Season	Base level: else	0.0000		
mOrigFY	L01_2001	Categorical Origination Fiscal Year	Orig_FY = 2001	0.2339	0.0501	<.0001
mOrigFY	L02_2002	Categorical Origination Fiscal Year	Orig_FY = 2002	0.1618	0.0373	<.0001
mOrigFY	L03_2003	Categorical Origination Fiscal Year	Orig_FY = 2003	0.2878	0.0316	<.0001
mOrigFY	L04_2004	Categorical Origination Fiscal Year	Orig_FY = 2004	0.1902	0.0206	<.0001
mOrigFY	L05_2005	Categorical Origination Fiscal Year	Orig_FY = 2005	0.0985	0.0182	<.0001
mOrigFY	L06_2006	Categorical Origination Fiscal Year	Orig_FY = 2006	0.1164	0.0122	<.0001
mOrigFY	L07_2007	Categorical Origination Fiscal Year	Orig_FY = 2007	-0.0581	0.0112	<.0001
mOrigFY	L08_2008	Categorical Origination Fiscal Year	Orig_FY = 2008	-0.1244	0.0111	<.0001
mOrigFY	L09_2009	Categorical Origination Fiscal Year	Orig_FY = 2009	-0.0173	0.0108	0.1088
mOrigFY	L10_2010	Categorical Origination Fiscal Year	Orig_FY = 2010	-0.0157	0.0114	0.1684
mOrigFY	Z11_2011	Categorical Origination Fiscal Year	Base level: else	0.0000		
mperiod_num_othr	L01_02	Categorical Period Number	period_number = 2	-0.9877	0.0264	<.0001
mperiod_num_othr	L02_03	Categorical Period Number	period_number = 3	-0.5197	0.0218	<.0001

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
mperiod_num_othr	L03_04	Categorical Period Number	period_number = 4	-0.2593	0.0199	<.0001
mperiod_num_othr	L04_05	Categorical Period Number	period_number = 5	-0.1128	0.0190	<.0001
mperiod_num_othr	Z06_99	Categorical Period Number	Base level: else	0.0000		
vperiodnbr_othr_pw1		Variate piecewise Period Number	median(0,period_number-6,20-6)	0.0181	0.0008	<.0001
vperiodnbr_othr_pw2		Variate piecewise Period Number	median(0,period_number-20,44-20)	0.0077	0.0005	<.0001
vperiodnbr_othr_pw3		Variate piecewise Period Number	max(0,period_number-44)	-0.0220	0.0011	<.0001
mp_appr_infl_1		Variate Appraisal Inflation		-4.7101	0.6654	<.0001
vp_appr_infl_othr_pw2		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.04,.05-.04)	4.6523	0.7089	<.0001
vp_appr_infl_othr_pw3		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.05,-.2-.05)	4.3486	0.6703	<.0001
vp_appr_infl_othr_pw4		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.2,-.3-.2)	3.8447	0.6498	<.0001
vp_appr_infl_othr_pw5		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.3,-.4-.3)	5.2413	1.0710	<.0001

CT2c Claim

The model parameters for the likelihood that an assigned loan ends with a CT2c at termination.

Table 26: Model Parameters – Likelihood of CT2c

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
Intercept				-13.8494	0.5094	<.0001
vUPBRatio_CT2C_pw1		Variate piecewise UPB Ratio1	if UPB_Ratio<.85 then UPB_Ratio; else .85;	10.7533	0.2513	<.0001
vUPBRatio_CT2C_pw2		Variate piecewise UPB Ratio1	if UPB_Ratio<=.85 then 0; else min(UPB_Ratio,1.5)-.85;	5.7488	0.2178	<.0001

## Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
mMinAge	L01_Miss	Categorical Minimum Age	min_age=.	0.7809	0.0514	<.0001
mMinAge	Z00_Base	Categorical Minimum Age	Base level: else	0.0000		
vminage_CT2C_pw1		Variate piecewise Minimum Age	median(0,min_age-62,95-62)	0.0457	0.0045	<.0001
vminage_CT2C_pw2		Variate piecewise Minimum Age	max(0,min_age-95)	-0.0877	0.0373	0.0186
v_appr_infl_CT2C_pw1		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.1,-.04--.1)	34.3697	8.1782	<.0001
v_appr_infl_CT2C_pw2		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.04,.05--.04)	16.8366	1.1992	<.0001
v_appr_infl_CT2C_pw3		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.05,.2-.05)	3.2659	0.4661	<.0001
v_appr_infl_CT2C_pw4		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.2,.3-.2)	5.0760	0.9909	<.0001

$$UPB\_Ratio^1 = C\_UPB\_Build\_Amt\_i / Property\_Value\_Curr$$

## CT2c Sales Price Model

The model parameters for the CT2c sales price model as a percentage of the UPB are shown below. This model includes an offset term of the natural log of the UPB.

Table 27: Model Parameters – CT2c Sales Price Model

Variable	Description	Description Detail	Estimate	StdErr	Pr > ChiSq
Intercept			2.6280	0.1392	<.0001
vperiodnbr_CT2c_pw1	Variate piecewise Period Number	min(43,period_number)	-0.0046	0.0009	<.0001
vpropval_pw1	Variate piecewise Property Value <sup>1</sup>	min(8,vpropval)	-0.3573	0.0109	<.0001
vpropval_pw2	Variate piecewise Property Value <sup>2</sup>	median(0,vpropval-8,10-8)	0.1917	0.0179	<.0001
vpropval_pw3	Variate piecewise	median(0,vpropval-10,15-10)	0.0288	0.0052	<.0001

## Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	Description	Description Detail	Estimate	StdErr	Pr > ChiSq
	Property Value <sup>1</sup>				
vpropval_pw4	Variate piecewise Property Value <sup>1</sup>	median(0,vpropval-15,30-15)	0.0113	0.0014	<.0001
vpropval_pw5	Variate piecewise Property Value <sup>1</sup>	median(0,vpropval-30,60-30)	-0.0023	0.0010	0.0224
vpropval_pw6	Variate piecewise Property Value <sup>1</sup>	max(0,vpropval-60)	-0.0038	0.0001	<.0001
v_appr_infl_CT2S_pw1	Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.1,-.03--.1)	-5.4331	1.7888	0.0024
v_appr_infl_CT2S_pw2	Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.03,.06--.03)	-2.1607	0.3276	<.0001
v_appr_infl_CT2S_pw3	Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.06,-.2-.06)	-0.7273	0.1584	<.0001
v_appr_infl_CT2S_pw4	Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.2,-.3-.2)	-0.9461	0.3400	0.0054
vminage_CT2c_pw1	Variate piecewise Minimum Age	median(0,min_age-62,95-62)	-0.0022	0.0010	0.0243
vminage_CT2c_pw2	Variate piecewise Minimum Age	max(0,min_age-95)	-0.0226	0.0080	0.0047
Scale			6.5448		

vpropval<sup>1</sup>= property\_value\_curr/10,000

## CT1 Claim Model

The model parameters for the likelihood of a CT1 claim given the loan has terminated in due and payable status and is not assigned are shown below.

Table 28: Model Parameters – Likelihood of CT1 Claim

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
Intercept				-14.0491	0.6573	<.0001
vUPBRatio_MRA_pw1		Variate piecewise UPB Ratio <sup>1</sup>	if UPB_Ratio<.20 then UPB_Ratio; else .2;	-7.2015	0.5384	<.0001

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
vUPBRatio_MRA_pw2		Variate piecewise UPB Ratio <sup>1</sup>	median(0,UPB_Ratio-.2,.35-.2)	-6.2041	0.5232	<.0001
vUPBRatio_MRA_pw3		Variate piecewise UPB Ratio <sup>1</sup>	median(0,UPB_Ratio-.35,.6-.35)	9.3170	0.1771	<.0001
vUPBRatio_MRA_pw4		Variate piecewise UPB Ratio <sup>1</sup>	median(0,UPB_Ratio-.6,.95-.6)	10.4855	0.0706	<.0001
vUPBRatio_MRA_pw5		Variate piecewise UPB Ratio <sup>1</sup>	median(0,UPB_Ratio-.95,1.5-.95)	5.0664	0.1847	<.0001
mMinage	L01_Miss	Categorical Minimum Age	min_age=.	1.1263	0.0127	<.0001
mMinage	Z00_Base	Categorical Minimum Age	Base level: else	0.0000		
vminage_MRA_pw1		Variate piecewise Minimum Age	median(0,min_age-62,67-62)	0.2195	0.0587	0.0002
vperiodnbr_mra_pw1		Variate piecewise period number	median(0,period_number-1,6-1)	0.6081	0.1070	<.0001
vperiodnbr_mra_pw2		Variate piecewise period number	median(0,period_number-6,9-6)	0.5907	0.0336	<.0001
vperiodnbr_mra_pw3		Variate piecewise period number	median(0,period_number-9,22-9)	0.1325	0.0026	<.0001
vperiodnbr_mra_pw4		Variate piecewise period number	median(0,period_number-22,35-22)	0.0451	0.0017	<.0001
vperiodnbr_mra_pw5		Variate piecewise period number	max(0,period_number-35)	0.0041	0.0013	0.0018
vp_appr_infl_mra_pw1		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.1,-.04--.1)	39.2876	5.3168	<.0001
vp_appr_infl_mra_pw2		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.04,.05--.04)	18.4718	0.5518	<.0001
vp_appr_infl_mra_pw3		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.05,.2-.05)	5.9300	0.1524	<.0001
vp_appr_infl_mra_pw4		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.2,.4-.2)	5.5192	0.2054	<.0001

$$UPB\_Ratio^1 = C\_UPB\_Build\_Amt\_i / Property\_Value\_Curr$$

## CT1 Sales Price Model

The model parameters for the CT1 sales price model are shown below. This model includes an offset term of the natural log of the UPB.

Table 29: Model Parameters – CT1 Sales Price Model

Variable	Description	Description Detail	Estimate	StdErr	Pr > ChiSq
Intercept			-0.3441	0.0937	0.0002
vperiodnbr_CT1_pw1	Variate piecewise Period Number	if period_number <=8 then period_number; else if 8<period_number<=40 then period_number-8; else 40-8;	-0.0026	0.0002	<.0001
vperiodnbr_CT1_pw2	Variate piecewise Period Number	if period_number <=40 then period_number; else if 40<period_number<=58 then period_number-40; else 58-40;	-0.0006	0.0001	<.0001
vpropval_pw1	Variate piecewise Property Value <sup>1</sup>	min(8,vpropval)	0.0138	0.0033	<.0001
vpropval_pw2	Variate piecewise Property Value <sup>1</sup>	median(0,vpropval-8,12-8)	0.0402	0.0021	<.0001
vpropval_pw3	Variate piecewise Property Value <sup>1</sup>	median(0,vpropval-12,15-12)	0.0293	0.0021	<.0001
vpropval_pw4	Variate piecewise Property Value <sup>1</sup>	median(0,vpropval-15,30-15)	0.0098	0.0003	<.0001
vpropval_pw6	Variate piecewise Property Value <sup>1</sup>	max(0,vpropval-50)	-0.0025	0.0003	<.0001
vUPB_CT1_Ratio_pw3	Variate piecewise UPB Ratio <sup>2</sup>	median(0,UPB_Ratio-47.8,59-47.8)	0.0097	0.0012	<.0001
vUPB_CT1_Ratio_pw4	Variate piecewise UPB Ratio <sup>2</sup>	median(0,UPB_Ratio-59,65.5-59)	0.0116	0.0014	<.0001
vUPB_CT1_Ratio_pw5	Variate piecewise UPB Ratio <sup>2</sup>	median(0,UPB_Ratio-65.5,88-65.5)	0.0016	0.0002	<.0001
vUPB_CT1_Ratio_pw6	Variate piecewise UPB Ratio <sup>2</sup>	median(0,UPB_Ratio-88,121-88)	-0.0011	0.0002	<.0001
vminage_CT1_pw1	Variate piecewise	median(0,min_age-70,77-70)	0.0028	0.0009	0.0019

Variable	Description	Description Detail	Estimate	StdErr	Pr > ChiSq
	Minimum Age				
vminage_CT1_pw2	Variate piecewise Minimum Age	median(0,min_age-77,91-77)	0.0088	0.0005	<.0001
vminage_CT1_pw3	Variate piecewise Minimum Age	max(0,min_age-91)	-0.0088	0.0025	0.0004
vp_appr_infl_CT1_pw1	Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.1,-.03--.1)	-10.0400	1.3351	<.0001
vp_appr_infl_CT1_pw2	Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.03,.05--.03)	-0.5186	0.1542	0.0008
vp_appr_infl_CT1_pw3	Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.05,.2-.05)	-1.1185	0.0387	<.0001
vp_appr_infl_CT1_pw4	Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.2,.3-.2)	-1.0474	0.0735	<.0001
vp_appr_infl_CT1_pw5	Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.3,.4-.3)	-1.9566	0.1357	<.0001
Scale			5.3368		

$$vpropval1 = \text{property\_value\_curr} / 10,000$$

$$UPB\_Ratio2 = C\_UPB\_Build\_Amt\_i / \text{Property\_Value\_Curr} * 100$$

## Model Validation

Model validation was accomplished by applying the models developed using the training set to the validation dataset. The application of this model to the validation data produces the predicted target variable for each model. The actual target variable is then compared to the predicted target variable to ensure the model fits the transition and sales price processes without over-fitting the actual data.

Specifically, we calculate the predicted probability of each transition for the logistic model and the expected sales price for each sales price model.

Decile charts are then created for each final model. All records are sorted, or ranked, by the predicted value. Ten equal sized decile groups are created with 10% of the records in each group. The sum of the actual result and the sum of the predicted result within each decile is calculated. The actual and predicted numbers are then compared for consistency. The objective of a model is to have a significant

spread in predicted values while maintaining a close relationship between the resulting actual and predicted values.

The validation charts for the claim termination models are shown below.

Figure 7: Model Validation – Likelihood of Refinance

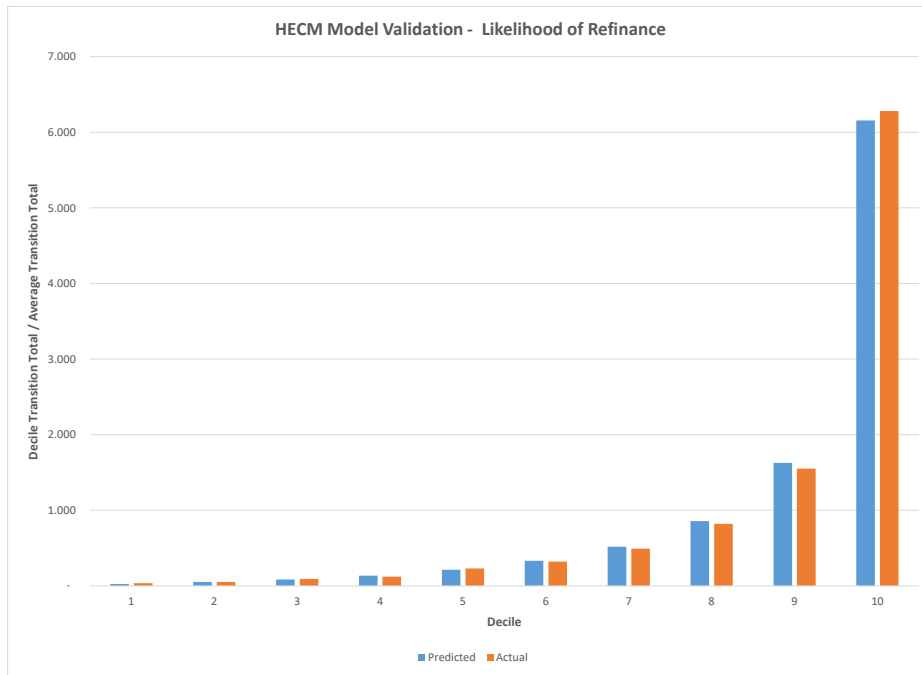


Figure 8: Model Validation - Likelihood of Non-Mortality Termination

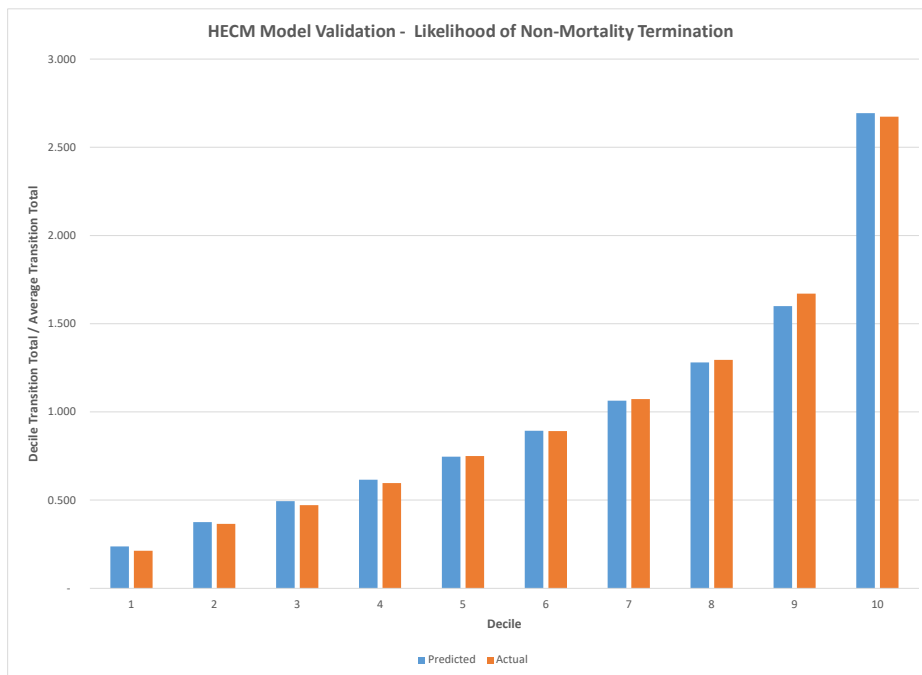


Figure 9: Model Validation - Likelihood of CT2c Claim

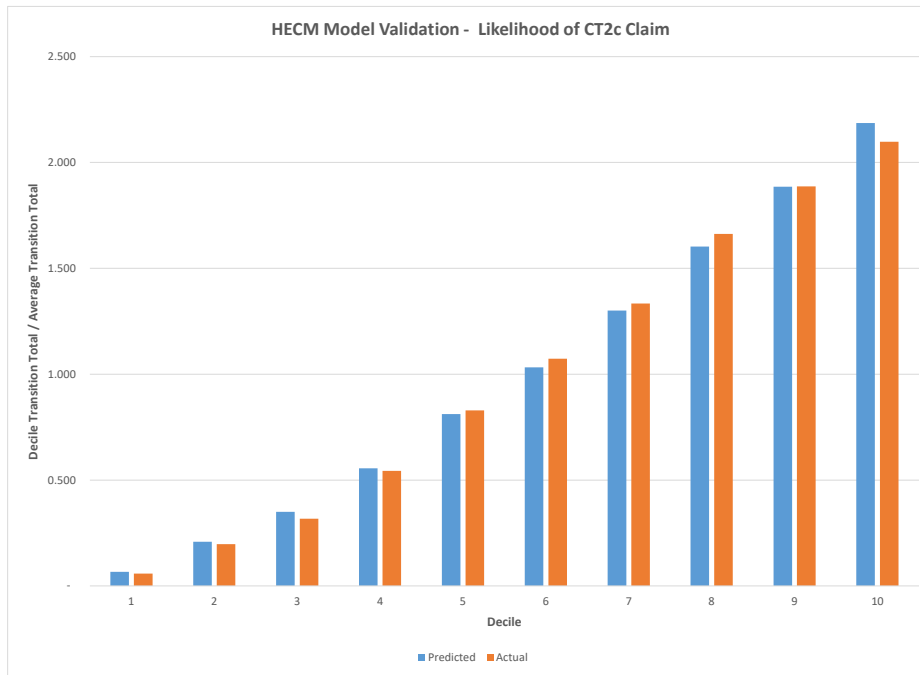


Figure 10: Model Validation – CT2c Sales Amount Model

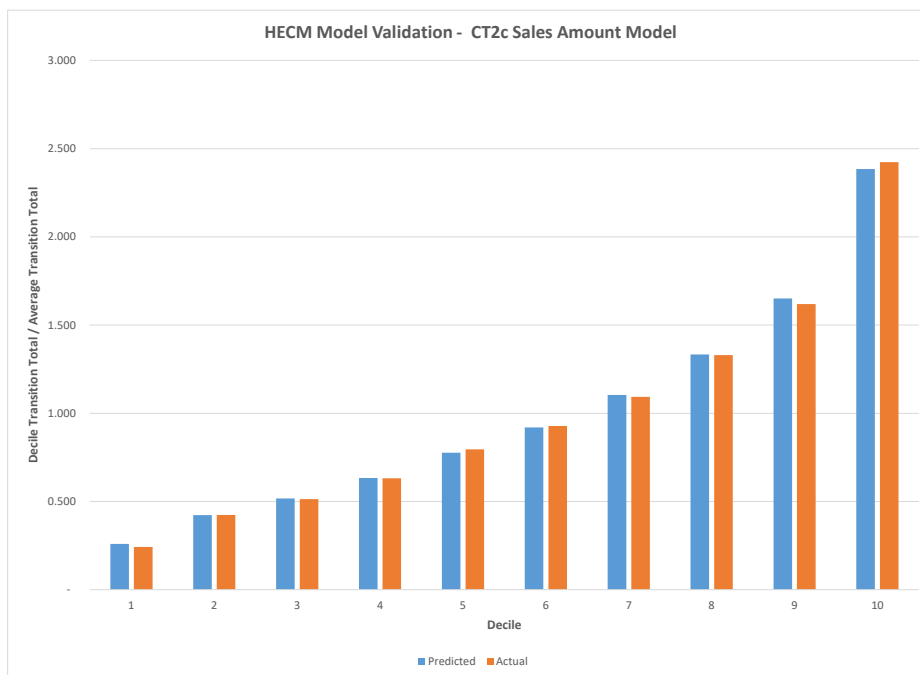


Figure 11: Model Validation – Likelihood of CT1 Claim

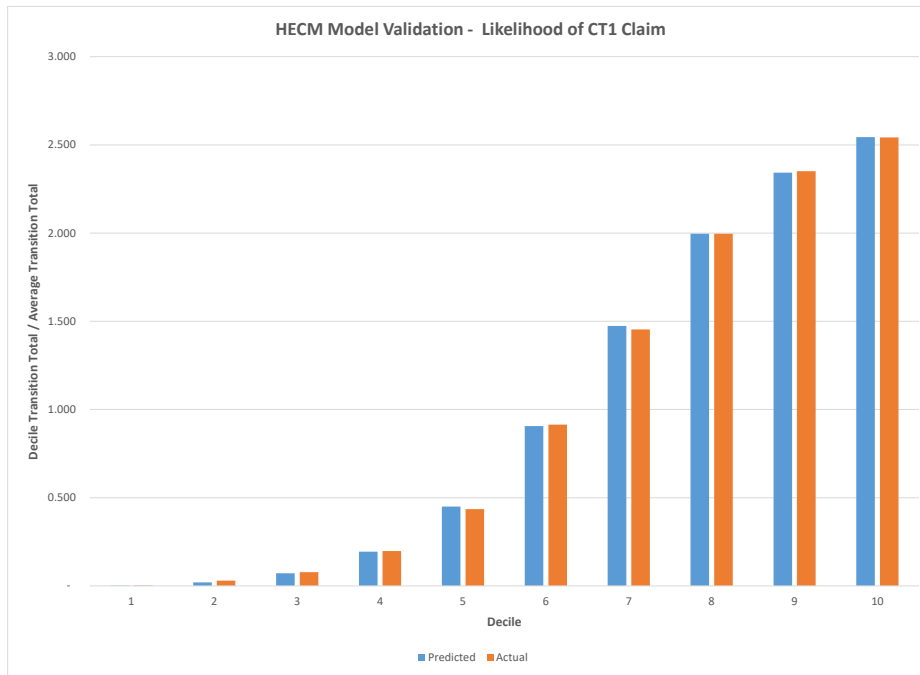
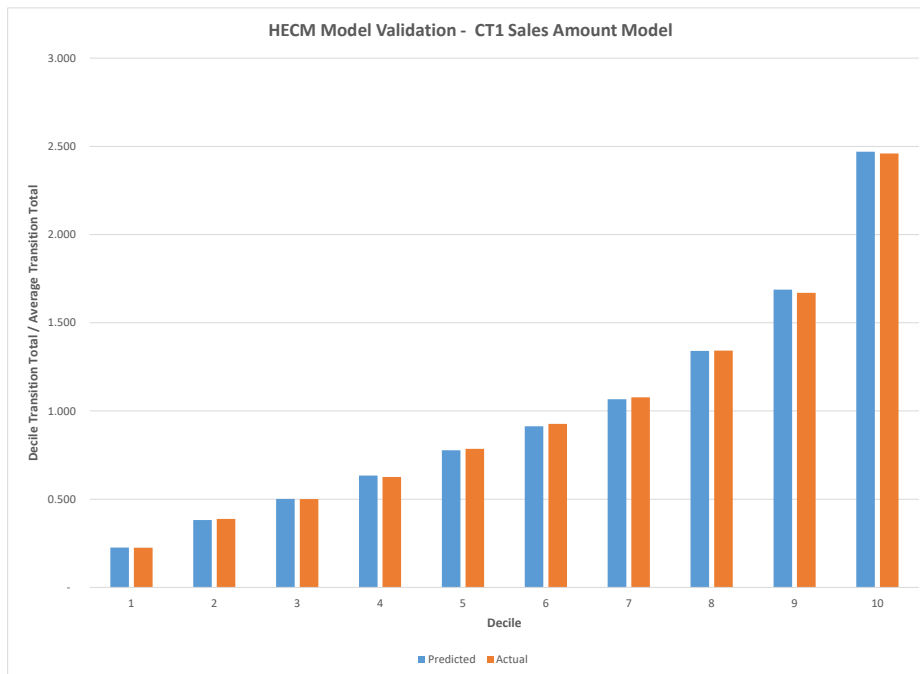


Figure 12: Model Validation – CT1 Sales Amount Model



## APPENDIX C: HECM CASH DRAW MODELS

Over 90% of HECM's have a line of credit associated with them. To estimate the Cash Flow NPV on the existing portfolio of HECM mortgages, we need to estimate the future unscheduled cash draws associated with mortgages with a line of credit.

### Model Specification

As these cash draws are not certain, we have developed predictive models to forecast cash draws. We have incorporated the following approach:

1. A binomial model is developed to estimate the likelihood of a cash draw occurring in a period.
2. If a cash draw is simulated, then the next step determines whether it is a full draw of all funds available through the LOC. There are two separate logistic models built for this: 1) A model built only on data from cohorts 2014 and subsequent for the first 8 quarters ("FD8" model), and 2) a model built on all data for quarters 9 and subsequent ("FD9+" model). The reason for the split is to account for the first twelve month disbursement period on the funds available for distribution from the LOC.
3. A Generalized Linear Model (GLM) is then developed to estimate the amount of the cash draw for the period if the cash draw is not a full draw.

Using the historical HECM data, for each quarter we develop indicators of whether or not a net positive unscheduled cash draw was taken from the line of credit during that quarter, and also the amount of the cash draw. We use this data to develop the binomial logistic models described above to estimate the likelihood of an unscheduled cash draw occurring during the quarter based on a series of explanatory variables, and to estimate the likelihood that this cash draw is a full draw. The explanatory variables used in the model are similar to those used for the termination models. These variables are described in Appendix B. Additionally, we include the amount remaining on the line of credit (LOCRemain) as an explanatory variable in the Cash Draw likelihood models.

For the estimated cash draw amount, we developed a model using the incremental line of credit cash draw from the historical HECM data. This incremental cash draw was used as the target variable, and we estimated the predicted amount of the cash draw based on a series of explanatory variables. The explanatory variables used in the model are the same as those for the termination models described in Appendix B and the Cash Draw likelihood models described above.

Models are also developed to project cash draws for taxes and insurance defaults. When a loan that has been assigned to HUD goes into default due to unpaid property taxes or insurance premiums, rather than letting the property default, HUD advances the tax or insurance payment. This amount is then added to the UPB. To project future tax and insurance default payments, Pinnacle has developed a model to predict the frequency of tax and insurance defaults, and has also developed a model to estimate the amount of the tax or insurance payment for those that have defaulted.

### Explanatory Variables

The following explanatory variables are used in the cash draw projection models. A general description of the variable is provided below, and more specific detail is included in the Model Parameters section.

- **Min age**: the youngest age amongst the borrower and co-borrowers. This variable is incorporated as a piecewise variate and a grouped categorical variable.
- **Season**: the quarter of the year. Possible values are 1 – January through March, 2 – April through June, 3 – July through September, and 4 – October through December. This variable is incorporated as a grouped categorical variable.
- **Alive**: Number of borrowers and co-borrowers that are alive. Possible values are 1 – alive and 0 – not alive. This variable is incorporated as a categorical variable.
- **Gender**: gender of the borrower and co-borrower. Possible values are 1 - borrower is male and co-borrower information is not available, 2 - borrower is female and the co-borrower information is not available, and 3 - there are two borrowers. This variable is incorporated as a grouped categorical variable.
- **Delta1yrinit**: change in the one-year CMT rate since loan origination. This variable is incorporated as a grouped categorical variable.
- **Loantyp**: type of HECM loan. Possible values are: 01 – Term, 02 - Line of Credit (LOC), 03 - Tenure; 04 - Term and LOC, 05 - Tenure and LOC, and 06 = Lump Sum. This variable is incorporated as a grouped categorical variable.
- **Lccap**: capped line of credit. If the loan is within its first year of origination, was originated after 2014 and has an LTV of greater than or equal to 60%, then the capped line of credit is 0, otherwise the capped line of credit is equal to the available line of credit. This variable is incorporated as a piecewise variate.
- **LocRemain**: line of credit remaining. This is calculated as a line of credit available divided the total line of credit x 100. This variable is incorporated as a piecewise variate.
- **Periodnbr**: the number of quarters since the inception of the mortgage. This variable is incorporated as a piecewise variate and a grouped categorical variable.

- **LTV**: ratio of the unpaid principal balance (UPB) to the current principal limit. This variable is incorporated as a piecewise variate and a grouped categorical variable.
- **TICnt**: the number of previous tax and insurance defaults. This variable is calculated as the count of prior periods where  $i\_TI\_Debit\_Amt$  is greater than \$100. This variable is incorporated as a grouped categorical variable.
- **Appraisal inflation**: predicted appraisal inflation, which is the percentage by which the original appraisal value reported to HUD is inflated. The appraisal inflation is provided by FHA and Summit-Milliman and is based on additional appraisal information obtained from VEROS. Pinnacle has relied on this appraisal inflation value without independent validation.

For variables that are incorporated as a piecewise variate, further information is provided on how these variates are specified in the Model Parameters section.

## Model Parameters

### Likelihood of Cash Draw

The model parameters for the likelihood of a cash draw are shown below.

Table 30: Model Parameters – Likelihood of Cash Draw

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
Intercept				-2.7321	0.0182	<.0001
mMinage_cdf	L01_62	Categorical Minimum Age	min_age=62	0.1927	0.0142	<.0001
mMinage_cdf	L02_63	Categorical Minimum Age	min_age=63	0.1543	0.0086	<.0001
mMinage_cdf	L03_64	Categorical Minimum Age	min_age=64	0.0920	0.0072	<.0001
mMinage_cdf	L04_65	Categorical Minimum Age	min_age=65	0.0220	0.0064	0.0006
mMinage_cdf	L05_95	Categorical Minimum Age	90<min_age<=95	-0.0173	0.0062	0.0052
mMinage_cdf	L06_99	Categorical Minimum Age	min_age>95	0.0224	0.0142	0.1145
mMinage_cdf	Z07_AO	Categorical Minimum Age	Base level: else	0.0000		
mSeason_CDF	A01	Categorical Season	period <201300 and mod(period,100) = 1	-0.1075	0.0046	<.0001
mSeason_CDF	A02	Categorical Season	period <201300 and mod(period,100) = 2	-0.0452	0.0045	<.0001
mSeason_CDF	A03	Categorical Season	period <201300 and mod(period,100) = 3	0.0080	0.0045	0.0736

## Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
mSeason_CDF	A04	Categorical Season	period <201300 and mod(period,100) = 4	0.0377	0.0044	<.0001
mSeason_CDF	B01	Categorical Season	period >=201300 and mod(period,100) = 1	-0.1586	0.0037	<.0001
mSeason_CDF	B02	Categorical Season	period >=201300 and mod(period,100) = 2	-0.1363	0.0038	<.0001
mSeason_CDF	B03	Categorical Season	period >=201300 and mod(period,100) = 3	-0.0722	0.0038	<.0001
mSeason	Z04	Categorical Season	Base level: else	0.0000		
mAlive	L02_2	Categorical Alive	Else	-0.2177	0.0022	<.0001
mAlive	Z01_1	Categorical Alive	Base level: num_alive=1	0.0000		
MGender	L01_M	Categorical Gender	(gender = 1 and borr_alive = 1) or (gender = 3 and coborr_gender_1=1 and coborr_1_alive=1)	-0.0455	0.0023	<.0001
MGender	Z02_O	Categorical Gender	Base level: else	0.0000		
mDeltaTy1Init	L01_2.0	Categorical Change in 1 year Treasury from Initial	Delta_T1Y_Init_p>2	0.0591	0.0029	<.0001
mDeltaTy1Init	Z02_Base	Categorical Change in 1 year Treasury from Initial	Base level: else	0.0000		
mloantyp	L01_01	Categorical Loan Type	loan_typ in ("01", "03", "04", "05", "06")	-0.4445	0.0044	<.0001
mloantyp	Z02_02	Categorical Loan Type	Base level: else	0.0000		
vLOCCap_CDF_pw1		Variate piecewise Line of Credit <sup>1</sup>	min(4500,loc_capped_i)	0.0010	0.0000	<.0001
vLOCCap_CDF_pw1*vLOCCap_CDF_pw1		Interacted Line of Credit	min(4500,loc_capped_i)	0.0000	0.0000	<.0001
vLOCCap_CDF_pw2		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-4500,12500-4500)	0.0001	0.0000	<.0001
vLOCCap_CDF_pw3		Variate piecewise Line of Credit <sup>1</sup>	max(0,loc_capped_i-12500)	0.0000	0.0000	<.0001
vLOCRemain_CDF_pw2		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-.45,1.4-.45)	1.1224	0.0115	<.0001
vLOCRemain_CDF_pw3		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-1.4,4.1-1.4)	-0.0282	0.0039	<.0001
vLOCRemain_CDF_pw4		Variate piecewise	median(0,loc_remaining-4.1,15.5-4.1)	-0.0158	0.0006	<.0001

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
		Line of Credit Remaining <sup>2</sup>				
vLOCRemain_CDF_pw5		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-15.1,40.5-15.5)	-0.0159	0.0002	<.0001
vLOCRemain_CDF_pw6		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-40.5,77-40.5)	-0.0180	0.0001	<.0001
vLOCRemain_CDF_pw7		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-77,93.4-77)	-0.0257	0.0004	<.0001
vLOCRemain_CDF_pw8		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-93.4,99-93.4)	-0.1138	0.0016	<.0001
vLOCRemain_CDF_pw9		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-99,99.9-99)	-0.4593	0.0139	<.0001
vLOCRemain_CDF_pw10		Variate piecewise Line of Credit Remaining <sup>2</sup>	max(0,loc_remaining-99.9)	1.2055	0.0988	<.0001
mperiod_num_CDF	L01_02	Categorical Period Number	period_number = 2	0.6528	0.0060	<.0001
mperiod_num_CDF	L02_03	Categorical Period Number	period_number = 3	0.3602	0.0059	<.0001
mperiod_num_CDF	L03_04	Categorical Period Number	period_number = 4	0.2592	0.0059	<.0001
mperiod_num_CDF	L04_05	Categorical Period Number	period_number = 5	0.5670	0.0052	<.0001
mperiod_num	Z06_99	Categorical Period Number	Base level: else	0.0000		
vPeriodNbr_CDF_pw1		Variate piecewise Period Number	median(0,period_number-5,24-5)	-0.0486	0.0002	<.0001
vPeriodNbr_CDF_pw2		Variate piecewise Period Number	median(0,period_number-24,40-24)	-0.0214	0.0003	<.0001
vPeriodNbr_CDF_pw3		Variate piecewise Period Number	median(0,period_number-40,52-40)	-0.0426	0.0009	<.0001
vPeriodNbr_CDF_pw4		Variate piecewise	max(0,period_number-52)	-0.0228	0.0019	<.0001

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
		Period Number				
vLTV_CDF_pw1		Variate piecewise Loan to Value	median(0,LTV-20,20)	0.0266	0.0007	<.0001
vLTV_CDF_pw2		Variate piecewise Loan to Value	median(0,LTV-20,75-20)	-0.0032	0.0001	<.0001
vLTV_CDF_pw3		Variate piecewise Loan to Value	median(0,period_number-75,95.5-75)	-0.0264	0.0003	<.0001
vLTV_CDF_pw4		Variate piecewise Loan to Value	median(0,LTV-95.5,98-95.5)	-0.0673	0.0025	<.0001
mLTV_CDF	0	Categorical Loan to Value	LTV <99.5	-0.1746	0.0075	<.0001
mLTV_CDF	1	Categorical Loan to Value	Base level: else	0.0000		
vp_appr_infl_CDF_pw2		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-- .04,.05--.04)	1.9772	0.0679	<.0001
vp_appr_infl_CDF_pw3		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.05,.2-.05)	0.3571	0.0261	<.0001
vp_appr_infl_CDF_pw4		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.2,.3-.2)	-0.9128	0.0626	<.0001
vp_appr_infl_CDF_pw5		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.3,.4-.3)	-0.4719	0.1367	0.0006

Likelihood of Full Cash Draw

The model parameters for the likelihood of a full cash draw in the first eight quarters are shown below.

Table 31: Model Parameters – Likelihood of Full Cash Draw (Quarters 1 – 8)

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
Intercept				-1.6455	0.1769	<.0001
mperiod_num_cd100	L01_02	Categorical Period Number	period_number = 2	-0.7127	0.1519	<.0001
mperiod_num_cd100	L02_03	Categorical Period Number	period_number = 3	-0.6506	0.1422	<.0001

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
mperiod_num_cd100	L03_04	Categorical Period Number	period_number = 4	0.8101	0.0657	<.0001
mperiod_num_cd100	L04_05	Categorical Period Number	period_number = 5	0.7100	0.1191	<.0001
mperiod_num_cd100	L05_06	Categorical Period Number	period_number = 6	0.1933	0.0379	<.0001
mperiod_num_cd100	L06_07	Categorical Period Number	period_number = 7	0.0457	0.0399	0.2518
mperiod_num_cd100	Z08_99	Categorical Period Number	Base level: else	0.0000		
vLOCCap_cd100_pw1		Variate piecewise Line of Credit <sup>1</sup>	min(3500,loc_capped_i)	-0.0004	0.0000	<.0001
vLOCCap_cd100_pw2		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-3500,10000-3500)	-0.0001	0.0000	<.0001
vLOCCap_cd100_pw3		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-10000,20000-10000)	-0.0001	0.0000	<.0001
vLOCCap_cd100_pw4		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-20000,100000-20000)	0.0000	0.0000	<.0001
vLOCCap_cd100_pw6		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-165000,300000-165000)	0.0000	0.0000	<.0001
vltv_cd100_pw1		Variate piecewise Loan to Value	min(55,LTV)	-0.0194	0.0034	<.0001
vltv_cd100_pw2		Variate piecewise Loan to Value	median(0,LTV-55,60-55)	0.6473	0.0206	<.0001
vltv_cd100_pw3		Variate piecewise Loan to Value	median(0,LTV-60,64-60)	-0.5967	0.0205	<.0001
vltv_cd100_pw4		Variate piecewise Loan to Value	median(0,LTV-64,95-64)	0.0530	0.0030	<.0001
vltv_cd100_pw5		Variate piecewise Loan to Value	max(0,LTV-95)	0.1869	0.0159	<.0001
vminage_cd100_pw1		Variate piecewise Minimum Age	median(0,min_age-62,78-62)	0.0057	0.0021	0.0068
vminage_cd100_pw2		Variate piecewise	max(0,min_age-78)	0.0359	0.0035	<.0001

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
		Minimum Age				
mSeason	L01	Categorical Season	mod(period,100) = 1	-0.0020	0.0266	0.9392
mSeason	L02	Categorical Season	mod(period,100) = 2	0.0184	0.0271	0.4980
mSeason	L03	Categorical Season	mod(period,100) = 3	0.0457	0.0268	0.0881
mSeason	Z04	Categorical Season	Base level: else	0.0000		
MGender	L01_M	Categorical Gender	(gender = 1 and borr_alive = 1) or (gender = 3 and coborr_gender_1=1 and coborr_1_alive=1)	0.1515	0.0205	<.0001
MGender	Z02_O	Categorical Gender	Base level: else	0.0000		
mAlive	L02_2	Categorical Alive	Else	0.1470	0.0207	<.0001
mAlive	Z01_1	Categorical Alive	Base level: num_alive=1	0.0000		
mloantyp	L01_01	Categorical Loan Type	loan_typ in ('01', '03', '04', '05', '06')	0.8792	0.0827	<.0001
mloantyp	Z02_02	Categorical Loan Type	Base level: else	0.0000		
vltv_cd100_pw2*mperiod_num5_cd100	L01_5	Interacted Loan to Value and Period Number	median(0,LTV-55,60-55) and period_number = 5	0.1083	0.0244	<.0001
vltv_cd100_pw2*mperiod_num5_cd100	Z02_AO	Interacted Loan to Value and Period Number	median(0,LTV-55,60-55) and period_number <> 5	0.0000		
vltv_cd100_pw3*mperiod_num5_cd100	L01_5	Interacted Loan to Value and Period Number	median(0,LTV-60,64-60) and period_number = 5	0.2420	0.0247	<.0001
vltv_cd100_pw3*mperiod_num5_cd100	Z02_AO	Interacted Loan to Value and Period Number	median(0,LTV-60,64-60) and period_number <> 5	0.0000		
vltv_cd100_pw4*mperiod_num5_cd100	L01_5	Interacted Loan to Value and Period Number	median(0,LTV-64,95-64) and period_number = 5	-0.0281	0.0036	<.0001
vltv_cd100_pw4*mperiod_num5_cd100	Z02_AO	Interacted Loan to Value and Period Number	median(0,LTV-64,95-64) and period_number <> 5	0.0000		
vltv_cd100_pw5*mperiod_num5_cd100	L01_5	Interacted Loan to Value and Period Number	max(0,LTV-95) and period_number = 5	-0.3105	0.0186	<.0001
vltv_cd100_pw5*mperiod_num5_cd100	Z02_AO	Interacted Loan to	max(0,LTV-95) and period_number <> 5	0.0000		

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
		Value and Period Number				
vp_appr_infl_CD100_pw2		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.04,.05--.04)	-1.1496	0.4063	0.0047
vp_appr_infl_CD100_pw4		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.2,.3-.2)	5.0530	1.3402	0.0002
vp_appr_infl_CD100_pw5		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.3,.4-.3)	-5.2577	2.8297	0.0632

The model parameters for the likelihood of a full cash draw in the ninth and subsequent quarters are shown below.

Table 32: Model Parameters – Likelihood of Full Cash Draw (Quarters 9+)

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
Intercept				-0.4897	0.2458	0.0463
vLOCCap_cd1009_pw0		Variate piecewise Line of Credit <sup>1</sup>	min(1000,loc_capped_i)	-0.0011	0.0000	<.0001
vLOCCap_cd1009_pw1		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-1000,3500-1000)	-0.0004	0.0000	<.0001
vLOCCap_cd1009_pw2		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-3500,10000-3500)	-0.0001	0.0000	<.0001
vLOCCap_cd1009_pw3		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-10000,20000-10000)	-0.0001	0.0000	<.0001
vLOCCap_cd1009_pw4		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-20000,100000-20000)	0.0000	0.0000	<.0001
vLOCCap_cd1009_pw5		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-100000,185000-100000)	0.0000	0.0000	0.0293
vLOCCap_cd1009_pw6		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-185000,300000-185000)	0.0000	0.0000	<.0001
vltv_cd1009_pw2		Variate piecewise Loan to Value	median(0,LTV-60,95-60)	0.0063	0.0010	<.0001
vltv_cd1009_pw3		Variate piecewise	max(0,LTV-95)	-0.0463	0.0043	<.0001

Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
		Loan to Value				
vminage_cd1009_pw1		Variate piecewise Minimum Age	median(0,min_age-62,78-62)	0.0074	0.0015	<.0001
vminage_cd1009_pw2		Variate piecewise Minimum Age	max(0,min_age-78)	0.0317	0.0016	<.0001
vperiodnbr_CD1009_pw1		Variate piecewise Period Number	median(0,period_number-9,25-9)	-0.0493	0.0011	<.0001
vperiodnbr_CD1009_pw2		Variate piecewise Period Number	max(0,period_number-25)	-0.0178	0.0012	<.0001
mSeason	L01	Categorical Season	mod(period,100) = 1	0.0525	0.0152	0.0006
mSeason	L02	Categorical Season	mod(period,100) = 2	0.1153	0.0153	<.0001
mSeason	L03	Categorical Season	mod(period,100) = 3	0.1810	0.0150	<.0001
mSeason	Z04	Categorical Season	Base level: else	0.0000		
MGender	L01_M	Categorical Gender	(gender = 1 and borr_alive = 1) or (gender = 3 and coborr_gender_1=1 and coborr_1_alive=1)	0.0483	0.0122	<.0001
MGender	Z02_O	Categorical Gender	Base level: else	0.0000		
mAlive	L02_2	Categorical Alive	Else	0.1400	0.0120	<.0001
mAlive	Z01_1	Categorical Alive	Base level: num_alive=1	0.0000		
mloantyp	L01_01	Categorical Loan Type	loan_typ in ("01", "03", "04", "05", "06")	0.5703	0.0267	<.0001
mloantyp	Z02_02	Categorical Loan Type	Base level: else	0.0000		
v_appr_infl_CD1009_pw1		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1--.1,-.04--.1)	10.7374	4.1606	0.0099
v_appr_infl_CD1009_pw2		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1--.04,.05--.04)	-4.2372	0.3804	<.0001
v_appr_infl_CD1009_pw3		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.05,.2-.05)	-2.1959	0.1350	<.0001
v_appr_infl_CD1009_pw4		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.2,.3-.2)	2.4931	0.2727	<.0001

## Cash Draw Amount Model

The model parameters for the cash draw amount are shown below.

Table 33: Model Parameters – Cash Draw Amount

Parameter	Level1	Description	Description Detail	DF	Estimate	StdErr	ProbChiSq
Intercept				1	6.4906	0.0176	<.0001
vLOCCap_cds_pw1		Variate piecewise Line of Credit <sup>1</sup>	min(1,loc_capped_i)	1	0.0144	0.0110	0.1894
vLOCCap_cds_pw2		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-1,3.5-1)	1	-0.0114	0.0034	0.0007
vLOCCap_cds_pw3		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-3.5,10-3.5)	1	-0.0310	0.0011	<.0001
vLOCCap_cds_pw4		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-10,15-10)	1	-0.0202	0.0012	<.0001
vLOCCap_cds_pw5		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-15,30-15)	1	-0.0169	0.0003	<.0001
vLOCCap_cds_pw6		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-30,125-30)	1	-0.0049	0.0000	<.0001
vLOCCap_cds_pw7		Variate piecewise Line of Credit <sup>1</sup>	median(0,loc_capped_i-125,200-125)	1	-0.0011	0.0001	<.0001
vLOCCap_cds_pw8		Variate piecewise Line of Credit <sup>1</sup>	max(0,loc_capped_i-200)	1	-0.0007	0.0001	<.0001
vminage_cds_pw1		Variate piecewise Min Age	median(0,min_age-62,67-62)	1	-0.0096	0.0013	<.0001
vminage_cds_pw2		Variate piecewise Min Age	median(0,min_age-67,75-67)	1	-0.0076	0.0004	<.0001
vminage_cds_pw3		Variate piecewise Min Age	median(0,min_age-75,85-75)	1	0.0079	0.0003	<.0001
vminage_cds_pw4		Variate piecewise Min Age	max(0,min_age-85)	1	0.0268	0.0006	<.0001
vperiodnbr_cds_pw1		Variate piecewise Period Number	median(0,period_number-5,10-5)	1	-0.0761	0.0007	<.0001
vperiodnbr_cds_pw2		Variate piecewise Period Number	median(0,period_number-10,20-10)	1	-0.0245	0.0003	<.0001

## Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Parameter	Level1	Description	Description Detail	DF	Estimate	StdErr	ProbChiSq
vperiodnbr_cds_pw3		Variate piecewise Period Number	median(0,period_number-20,54-20)	1	-0.0083	0.0002	<.0001
vperiodnbr_cds_pw4		Variate piecewise Period Number	max(0,period_number-54)	1	-0.0193	0.0021	<.0001
vltv_cds_pw1		Variate piecewise Loan to Value	min(20,LTV)	1	-0.0082	0.0007	<.0001
vltv_cds_pw2		Variate piecewise Loan to Value	median(0,LTV-20,60-20)	1	0.0112	0.0001	<.0001
vltv_cds_pw3		Variate piecewise Loan to Value	max(0,LTV-60)	1	0.0049	0.0001	<.0001
mltv_cds	L01_60	Categorical Loan to Value	LTV=60 and orig_fy>2014 and period_number=5 and loan_typ="02"	1	0.5111	0.0139	<.0001
mltv_cds	Z02_AO	Categorical Loan to Value	Base level: else	1	0.0000		
mSeason	L01	Categorical Season	mod(period,100) = 1	1	-0.0002	0.0025	0.9434
mSeason	L02	Categorical Season	mod(period,100) = 2	1	0.0249	0.0025	<.0001
mSeason	L03	Categorical Season	mod(period,100) = 3	1	0.0349	0.0025	<.0001
mSeason	Z04	Categorical Season	Base level: else	1	0.0000		
MGender	L01_M	Categorical Gender	(gender = 1 and borr_alive = 1) or (gender = 3 and coborr_gender_1=1 and coborr_1_alive=1)	1	0.0349	0.0021	<.0001
MGender	Z02_O	Categorical Gender	Base level: else	1	0.0000		
mAlive	L02_2	Categorical Alive	Else	1	0.0538	0.0020	<.0001
mAlive	Z01_1	Categorical Alive	Base level: num_alive=1	1	0.0000		
mloantyp	L01_01	Categorical Loan Type	loan_typ in ('01', '03', '04', '05', '06')	1	-0.1026	0.0042	<.0001
mloantyp	Z02_02	Categorical Loan Type	Base level: else	1	0.0000		
vLOCRemain_cds_pw1		Variate piecewise Line of Credit Remaining <sup>2</sup>	min(6.4,loc_remaining)	1	-0.0176	0.0016	<.0001
vLOCRemain_cds_pw2		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-6.4,14.6-6.4)	1	-0.0227	0.0009	<.0001
vLOCRemain_cds_pw3		Variate piecewise Line of	median(0,loc_remaining-14.6,29-14.6)	1	-0.0121	0.0004	<.0001

## Economic Net Worth from Home Equity Conversion Mortgage Insurance-In-Force

Fiscal Year 2021 Independent Actuarial Review

November 12, 2021

Parameter	Level1	Description	Description Detail	DF	Estimate	StdErr	ProbChiSq
		Credit Remaining <sup>2</sup>					
vLOCRemain_cds_pw4		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-29,53.5-29)	1	-0.0081	0.0002	<.0001
vLOCRemain_cds_pw5		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-53.5,85.5-53.5)	1	-0.0058	0.0001	<.0001
vLOCRemain_cds_pw6		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-85.5,88.5-85.5)	1	-0.0166	0.0021	<.0001
vLOCRemain_cds_pw7		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-88.5,96.25-88.5)	1	-0.0118	0.0012	<.0001
vLOCRemain_cds_pw8		Variate piecewise Line of Credit Remaining <sup>2</sup>	median(0,loc_remaining-96.25,97.5-96.25)	1	0.1050	0.0093	<.0001
vLOCRemain_cds_pw9		Variate piecewise Line of Credit Remaining <sup>2</sup>	max(0,loc_remaining-97.5)	1	0.1946	0.0040	<.0001
vp_appr_infl_cds_pw2		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.04,.05--.04)	1	-0.3746	0.0598	<.0001
vp_appr_infl_cds_pw3		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.05,.2-.05)	1	-0.3228	0.0226	<.0001
vp_appr_infl_cds_pw4		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.2,.3-.2)	1	0.6240	0.0552	<.0001
vp_appr_infl_cds_pw5		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.3,.4-.3)	1	-0.5005	0.1226	<.0001
Scale				0	0.9060		

Variate Line of Credit1: if (period\_number<=4 and orig\_fy>=2014 and LTV>=60) then loc\_capped\_i=0;  
else loc\_capped\_i = loc\_avail\_i / 1000;  
LOC\_remaining2 = (Loc\_avail\_i/loc\_total\_i)\*100;

## Tax and Insurance Default Frequency Model

The model parameters for the tax and insurance default frequency model are shown below.

Table 34: Model Parameters – Tax and Insurance Default Frequency Model

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
Intercept				-4.5182	0.0124	<.0001
mSeason	L01	Categorical Season	mod(period,100) = 1	-0.0815	0.0050	<.0001
mSeason	L02	Categorical Season	mod(period,100) = 2	0.0693	0.0049	<.0001
mSeason	L03	Categorical Season	mod(period,100) = 3	0.0938	0.0049	<.0001
mSeason	Z04	Categorical Season	Base level: else	0.0000		
mTICnt	L01	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 1	2.1967	0.0049	<.0001
mTICnt	L02	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 2	2.8160	0.0058	<.0001
mTICnt	L03	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 3	3.0658	0.0067	<.0001
mTICnt	L04	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 4	3.1816	0.0078	<.0001
mTICnt	L05	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 5	3.3091	0.0090	<.0001
mTICnt	L06	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 6	3.4282	0.0104	<.0001
mTICnt	L07	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 7	3.4933	0.0122	<.0001
mTICnt	L08	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 8	3.5914	0.0143	<.0001
mTICnt	L09	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 9	3.6511	0.0168	<.0001
mTICnt	L10	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 10	3.6653	0.0199	<.0001
mTICnt	L11	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 11	3.8009	0.0236	<.0001
mTICnt	L12	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 12	3.7593	0.0281	<.0001

Variable	ClassVal0	Description	Description Detail	Estimate	StdErr	ProbChiSq
mTICnt	L13	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 13	3.9058	0.0338	<.0001
mTICnt	L14	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 14	3.8941	0.0407	<.0001
mTICnt	L15	Categorical Count of Tax and Ins Default <sup>1</sup>	TI_Debit_Cnt_i = 15	3.8802	0.0493	<.0001
mTICnt	L16	Categorical Count of Tax and Ins Default <sup>1</sup>	Else	4.0038	0.0368	<.0001
mTICnt	Z00	Categorical Count of Tax and Ins Default <sup>1</sup>	Base level: TI_Debit_Cnt_i = 0	0.0000		
vperiodnbr_TIDF_pw1		Variate piecewise Period Number	median(0,period_number-7,29-7)	-0.0205	0.0003	<.0001
vperiodnbr_TIDF_pw2		Variate piecewise Period Number	median(0,period_number-29,54-29)	-0.0254	0.0004	<.0001
vperiodnbr_TIDF_pw3		Variate piecewise Period Number	median(0,period_number-54,67-54)	-0.0326	0.0031	<.0001
vp_appr_infl_TID_pw2		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1--.04,.05--.04)	1.6096	0.1516	<.0001
vp_appr_infl_TID_pw3		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.05,-.2-.05)	0.5815	0.0448	<.0001
vp_appr_infl_TID_pw4		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.2,-.3-.2)	0.8332	0.0903	<.0001
vp_appr_infl_TID_pw5		Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.3,-.4-.3)	0.6891	0.1461	<.0001

### Tax and Insurance Default Amount Model

The model parameters for the tax and insurance default amount model are shown below.

Table 35: Model Parameters – Tax and Insurance Default Amount Model

Variable	Description	Description Detail	Estimate	StdErr	ProbChiSq
Intercept			0.9645	0.1575	<.0001

Variable	Description	Description Detail	Estimate	StdErr	ProbChiSq
vperiodnbr_TIDS	Period Number	mod(period,100) = 1	-0.0121	0.0020	<.0001
vProperty_Value_TIDS	Categorical Season	mod(period,100) = 2	0.0002	0.0001	<.0001
vp_appr_infl_tids_pw2	Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.04,.05--.04)	6.2499	1.7884	0.0005
vp_appr_infl_tids_pw3	Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.05,.2-.05)	3.6405	0.5680	<.0001
vp_appr_infl_tids_pw4	Variate piecewise Appraisal Inflation	median(0,p_appr_infl_1-.2,.4-.2)	-4.1056	0.8701	<.0001
Scale			0.6602		

### Model Validation

Model validation was accomplished by applying the models developed using the training set to the validation dataset. The application of this model to the validation data produces the probability of a cash draw or a predicted cash draw amount. The actual target variable is then compared to the predicted target variable to ensure the model fits the cash draw process without over-fitting the actual data.

Specifically we calculate the predicted probability of the cash draw or the predicted amount for the cash draw amount models. The actual result is 1.0 if the cash draw was taken and 0.0 if it was not, or an actual cash draw amount for the cash draw amount model. The probability of a cash draw or the predicted amount of the cash draw for each record in the validation dataset is derived from the model parameters.

Decile charts are then created for each final cash draw likelihood or average draw amount. All records are sorted, or ranked, by the predicted value. Ten equal sized decile groups are created with 10% of the records in each group. The sum of the actual result and the sum of the predicted result within each decile is calculated. The actual and predicted numbers are then compared for consistency. The objective of a model is to have a significant spread in predicted values while maintaining a close relationship between the resulting actual and predicted values.

The validation charts for the cash draw models are shown below.

Figure 13: Model Validation - Likelihood of Cash Draw

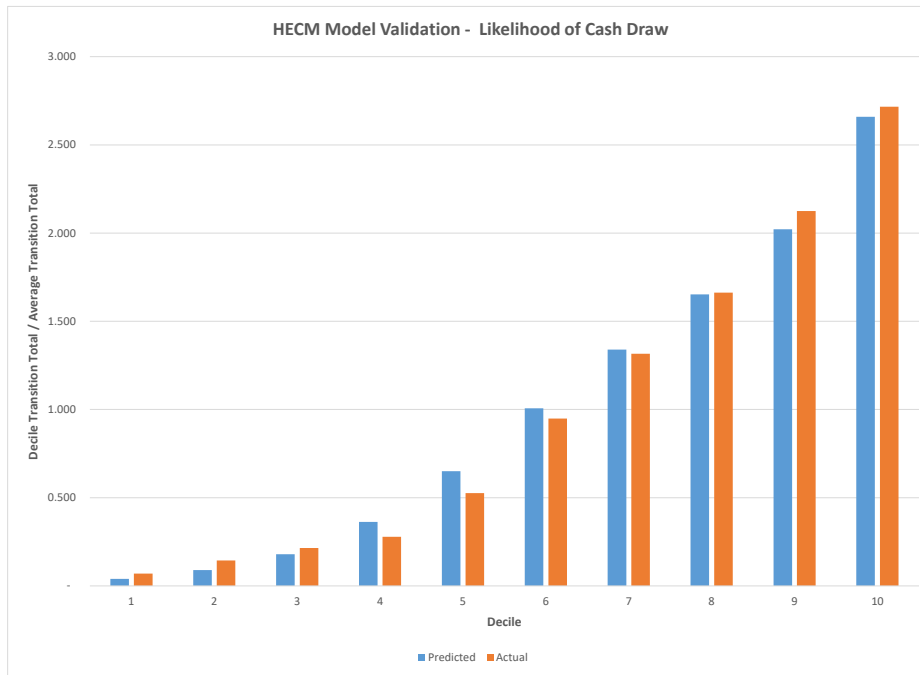


Figure 14: Model Validation - Likelihood of Full Cash Draw (Quarters 1 – 8)

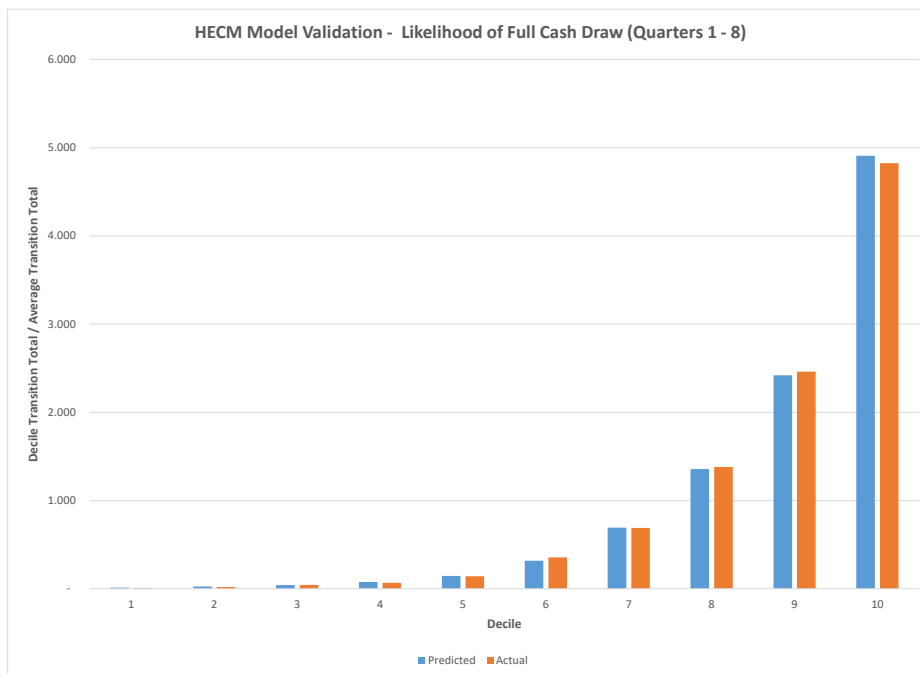


Figure 15: Model Validation - Likelihood of Full Cash Draw (Quarters 9+)

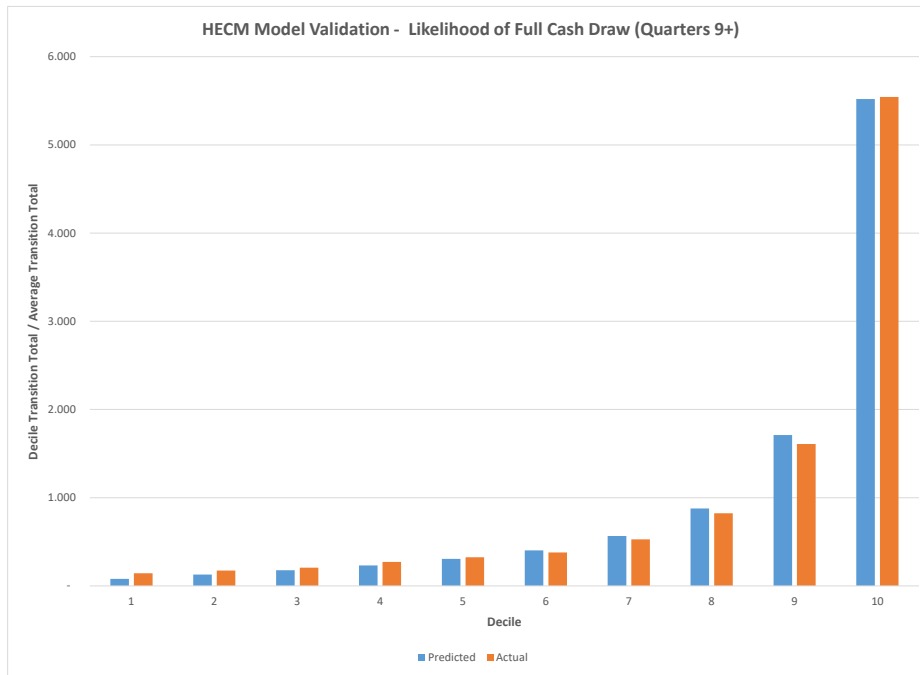
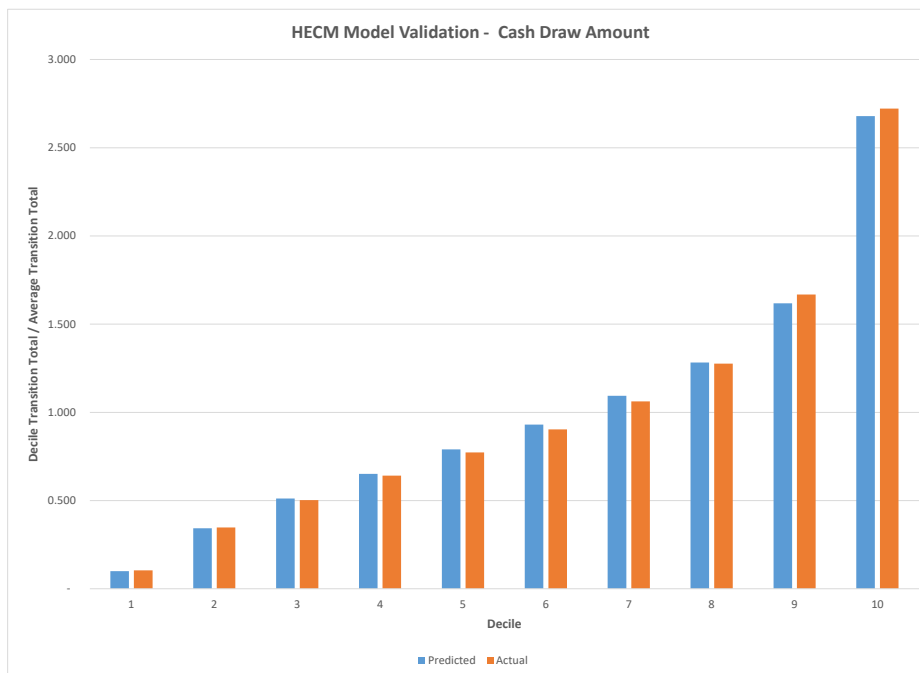


Figure 16: Model Validation – Cash Draw Amount



The validation chart for the tax and insurance default model is shown below.

Figure 17: Model Validation – Tax and Insurance Default Likelihood Model

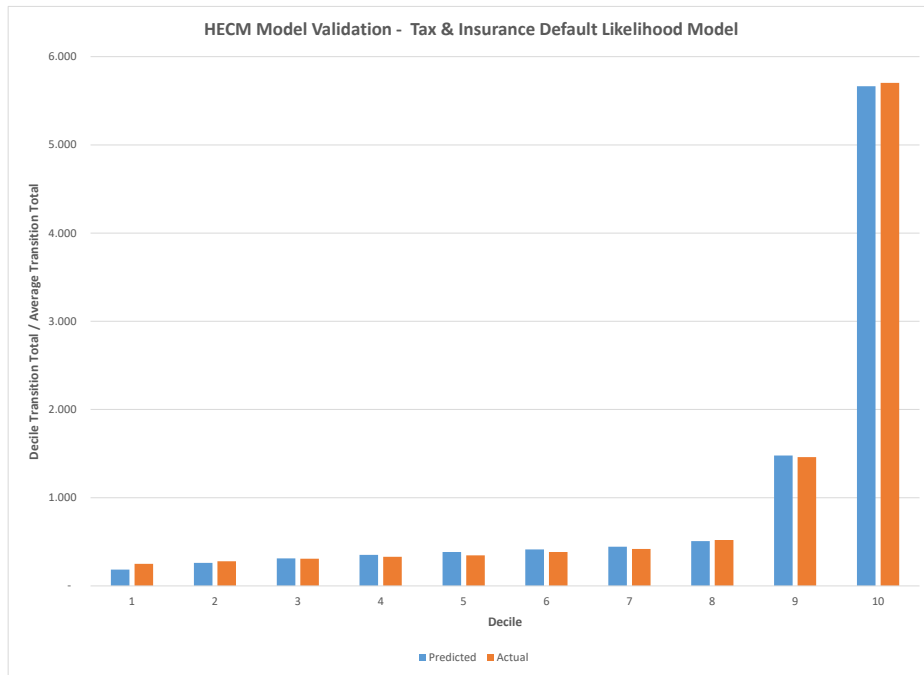
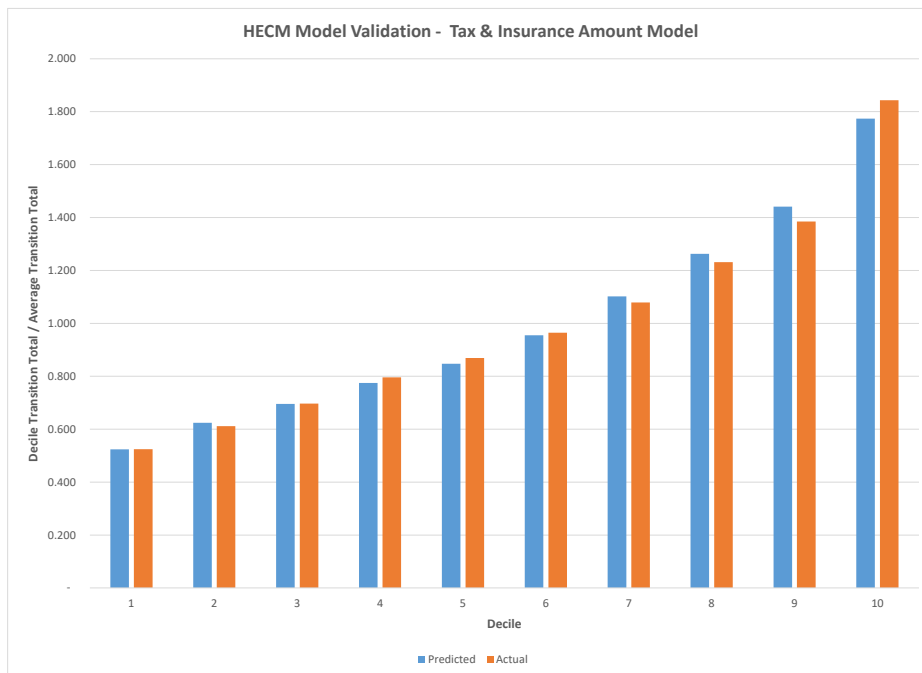


Figure 18: Model Validation - Tax and Insurance Default Amount Model



## APPENDIX D: ECONOMIC SCENARIOS

To measure the possible variation in MMI's Cash Flow NPV on the existing portfolio, we developed a baseline projection using OMB Economic Assumptions and projections for ten additional deterministic economic scenarios from Moody's. For this analysis, we used the Moody's October 2021 forecast of the U.S. economy. For purposes of our analysis, the components of Moody's forecast include:

- HPI at the MSA, state, regional and national levels
- One-year CMT rate
- Three-year CMT rate
- Five-year CMT rate
- 10-year CMT rate
- 30-year CMT rate
- Commitment rate on 30-year fixed-rate mortgages (FRM)
- Unemployment rates at the MSA, state, regional and national levels
- GDP

### Alternative Scenarios

To assess the effect of alternative economic scenarios on the Cash Flow NPV, ten alternative scenarios from Moody's were used. The ten Moody's scenarios are:

- Baseline
- Alternative 0 – Upside (4<sup>th</sup> Percentile)
- Alternative 1 – Upside (10<sup>th</sup> Percentile)
- Alternative 2 – Downside (75<sup>th</sup> Percentile)
- Alternative 3 – Downside (90<sup>th</sup> Percentile)
- Alternative 4 – Downside (96<sup>th</sup> Percentile)
- Slower Trend Growth
- Stagflation
- Next-Cycle Recession
- Low Oil Price

The Moody's projections provide a range of better than expected economic assumptions and worse than expected economic assumptions. This range of assumptions produces a range of Cash Flow NPV projections.

**Graphical Depiction of the Scenarios**

Figure 19 shows the future movements of the HPI under the baseline and the alternative economic scenarios. In the Baseline scenario, the HPI increases throughout the entire projection period. The rate of increase is about 1.0% per year through 2028, and then increases to about 3.5% per year for the remainder of the projection period.

Figure 19: Paths of the Future National House Price Index in Different Scenarios

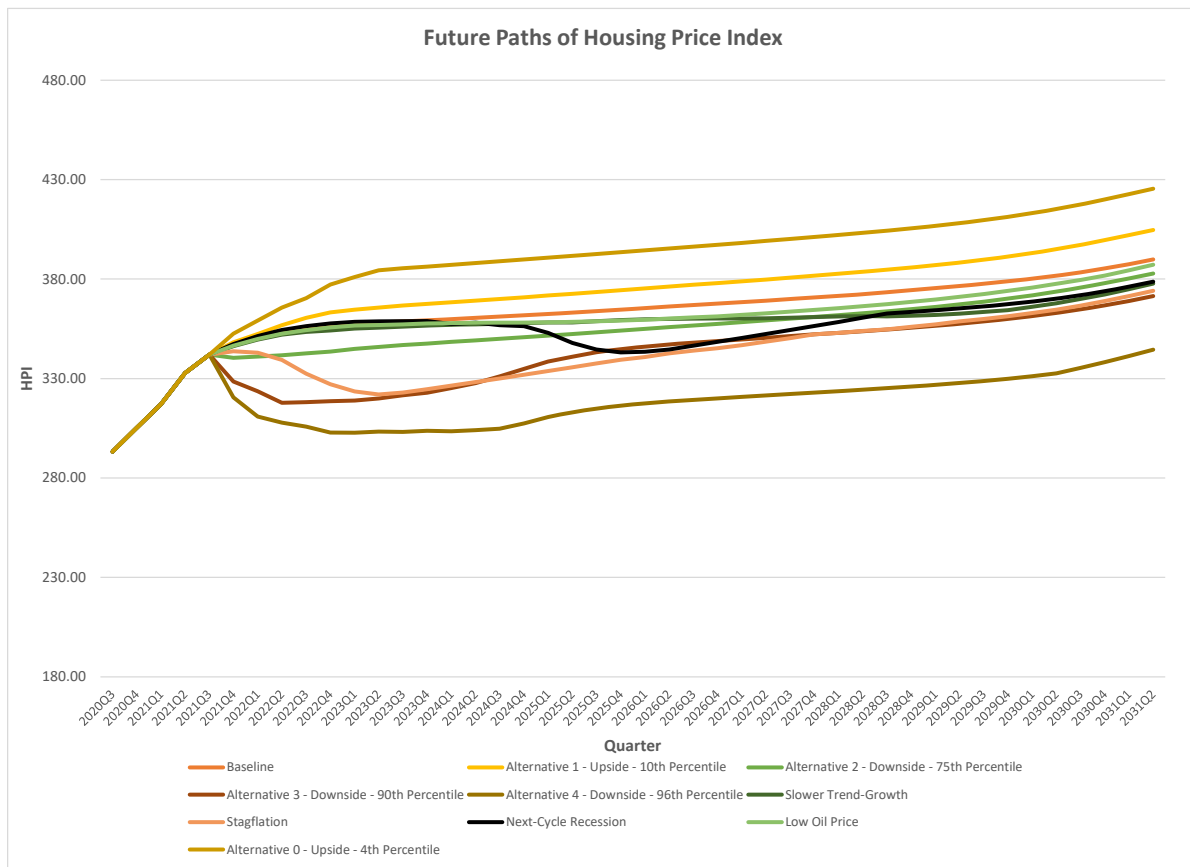


Figure 20 shows the forecasted mortgage rate of 30-year fixed-rate mortgages for the ten Moody’s scenarios. For the Moody’s Baseline Scenario, the mortgage interest rate increases through 2027 to about 4.9%, and then levels off near this rate.

Figure 20: Paths of the Future Mortgage Rate

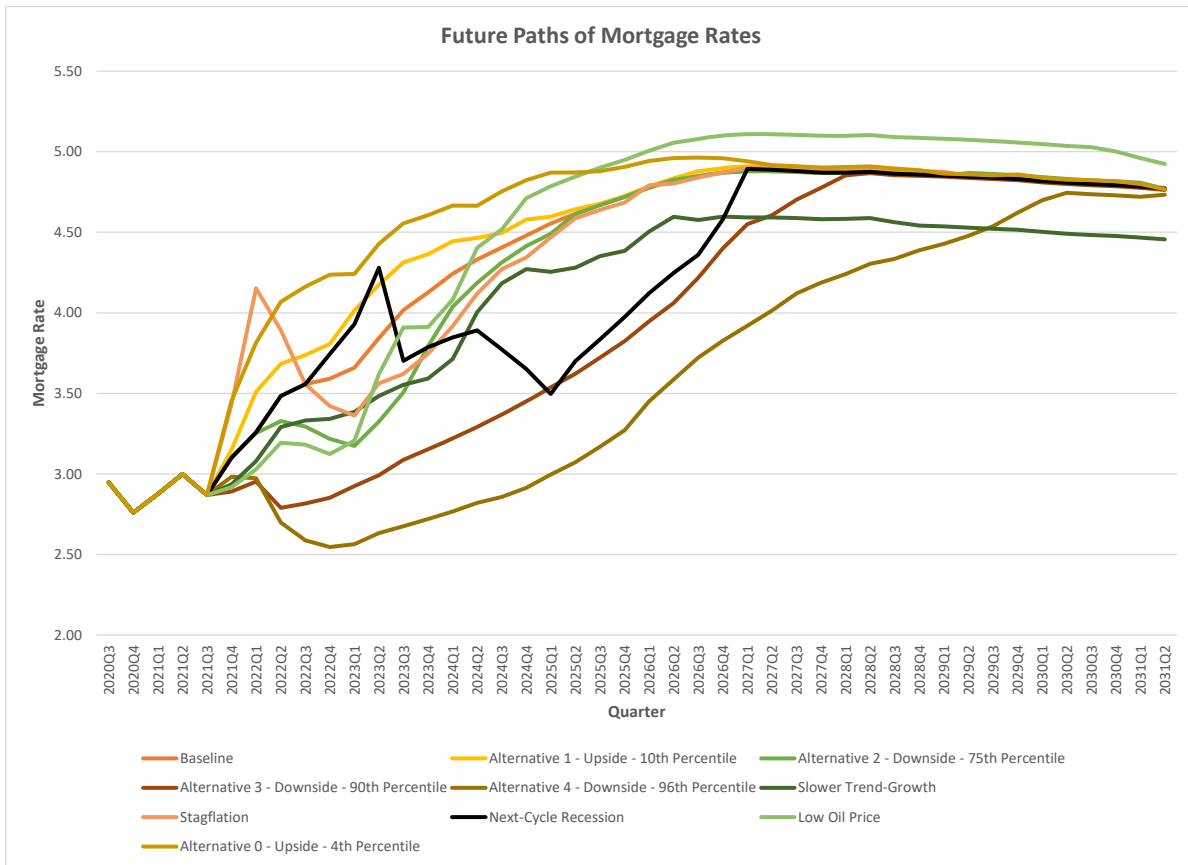
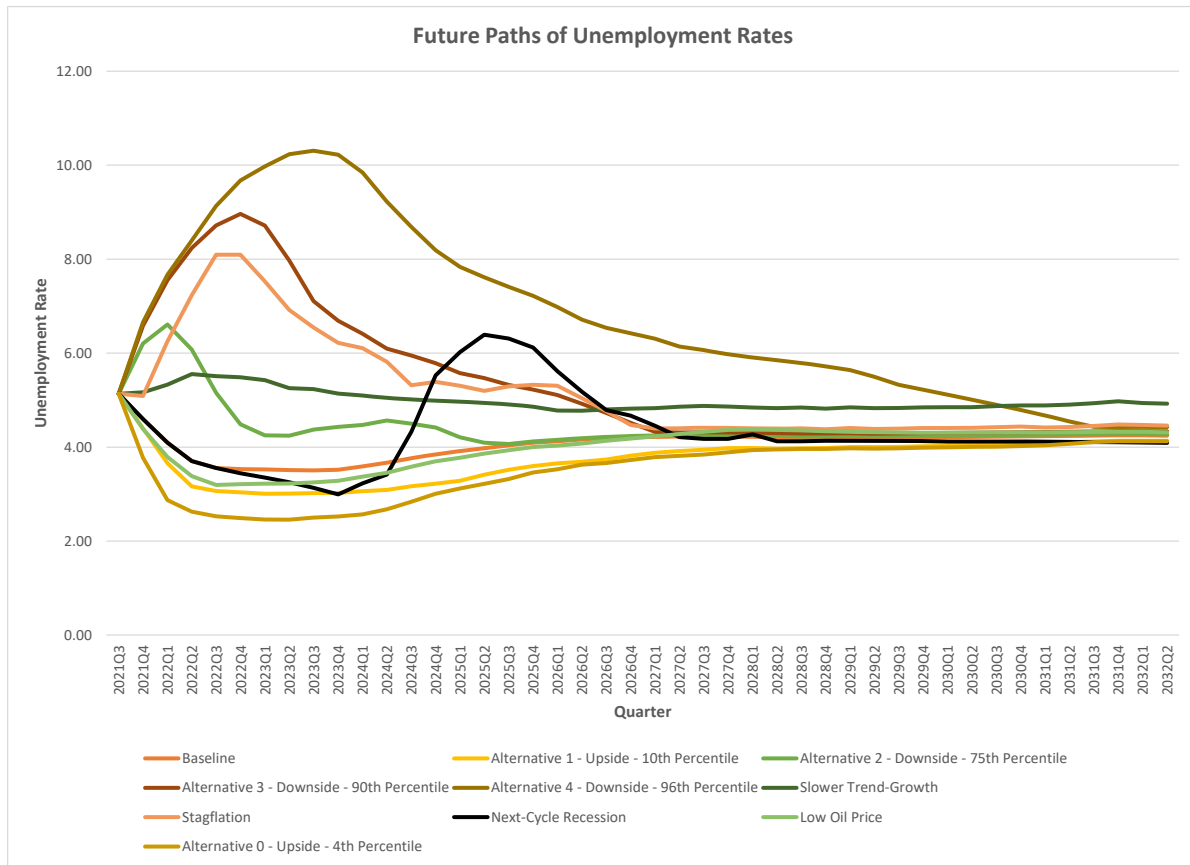


Figure 21 shows the forecasted unemployment rate under alternative economic scenarios. Under the Moody’s Baseline forecast, the unemployment rate is projected to decrease through 2022 to approximately 3.5%, and then increases to 4.7% by 2026. The rate then remains steady at that level for the remainder of the projection period.

Figure 21: Paths of Future National Unemployment Rate



**Stochastic Simulation**

This section describes the stochastic models fitted to generate the economic variables simulations used in the projection of Cash Flow NPV.

The economic variables modeled herein as stochastic for computing expected present values include:

- Three month CMT rates
- Six month CMT rates
- 10-year CMT rates
- One rear CMT rates
- 30-year CMT rates
- 30-year FRMrates
- FHFA National Purchase Only House Price Index (HPI-PO)
- Unemployment Rates
- Gross Domestic Product (GDP)
- Small Business Normalized Optimism Index (NOI)

- Consumer Confidence Index (CCI)
- London Interbank Offered Rates (LIBOR)
- Secured Overnight Financing Rates (SOFR)

## Historical Data

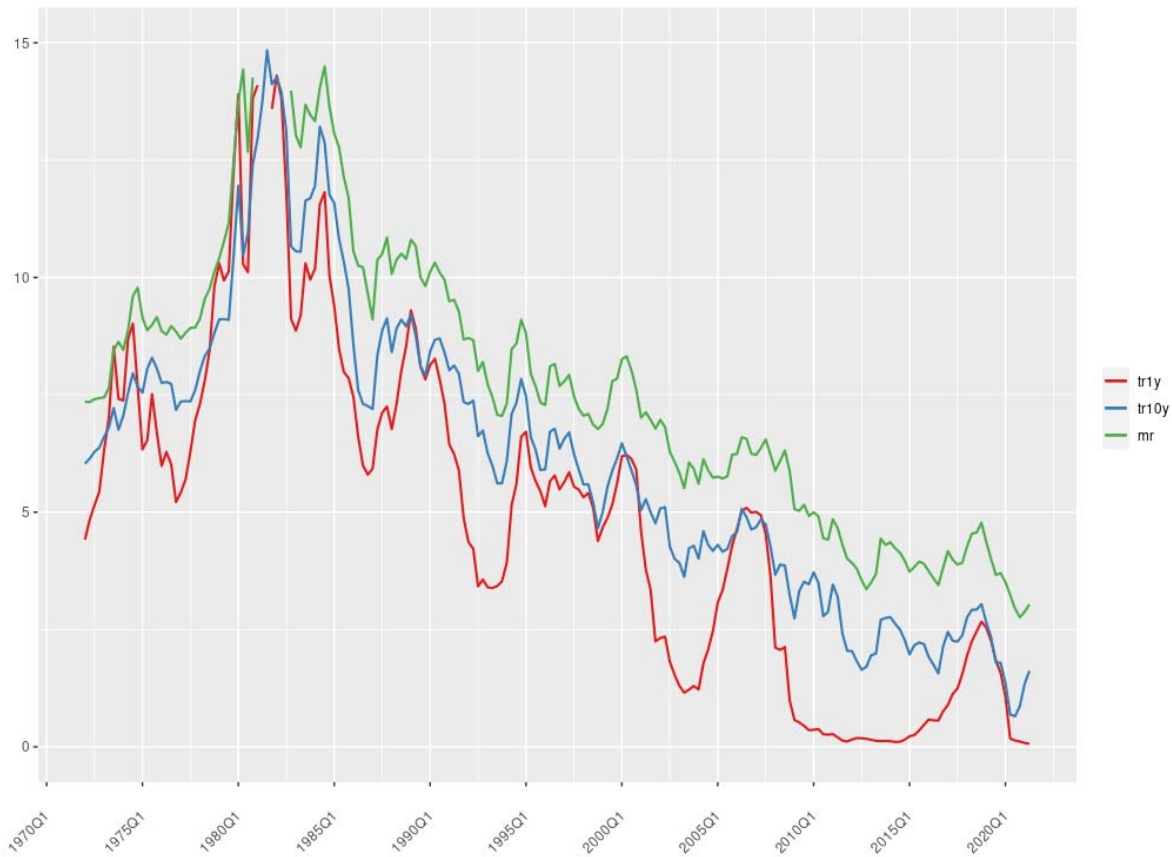
### A. Interest Rates

Figure 22 shows historical interest rates since 1971.

This graph illustrates the variability of interest rates over time and the consistent spread between rates. Shown are the one-year CMT rate (tr1y), 10-year CMT rate (tr10y) and the 30-year FRM rate (mr).

High inflation rates caused by the global oil crisis in the late 1970's was the major factor for the historically high level in early 1980's. The Federal Reserve shifted its monetary policy from managing interest rates to managing the money supply as a way to influence interest rates after this period of time. The one-year CMT rate was around 5% in calendar year 1971 and increased steadily to its peak of 16.31% in the third quarter of calendar year 1981. After that, it followed a decreasing trend and reached a low of 0.10% in second quarter of calendar year 2014. Since then rates had started a slow upward trend up until recently where there is a sharp downward trend reaching a historic low of 0.06% in 2021, a result of the COVID-19 pandemic.

Figure 22: Historical Interest Rates (%)



Multiple short-term rates were included in these simulations, including three, six and 12 month CMT rates, SOFR, and LIBOR. Figure 2 illustrates the close relationship between these rates with the most volatility in LIBOR.

Figure 23: Historical Shorter-Term Interest Rates (%)

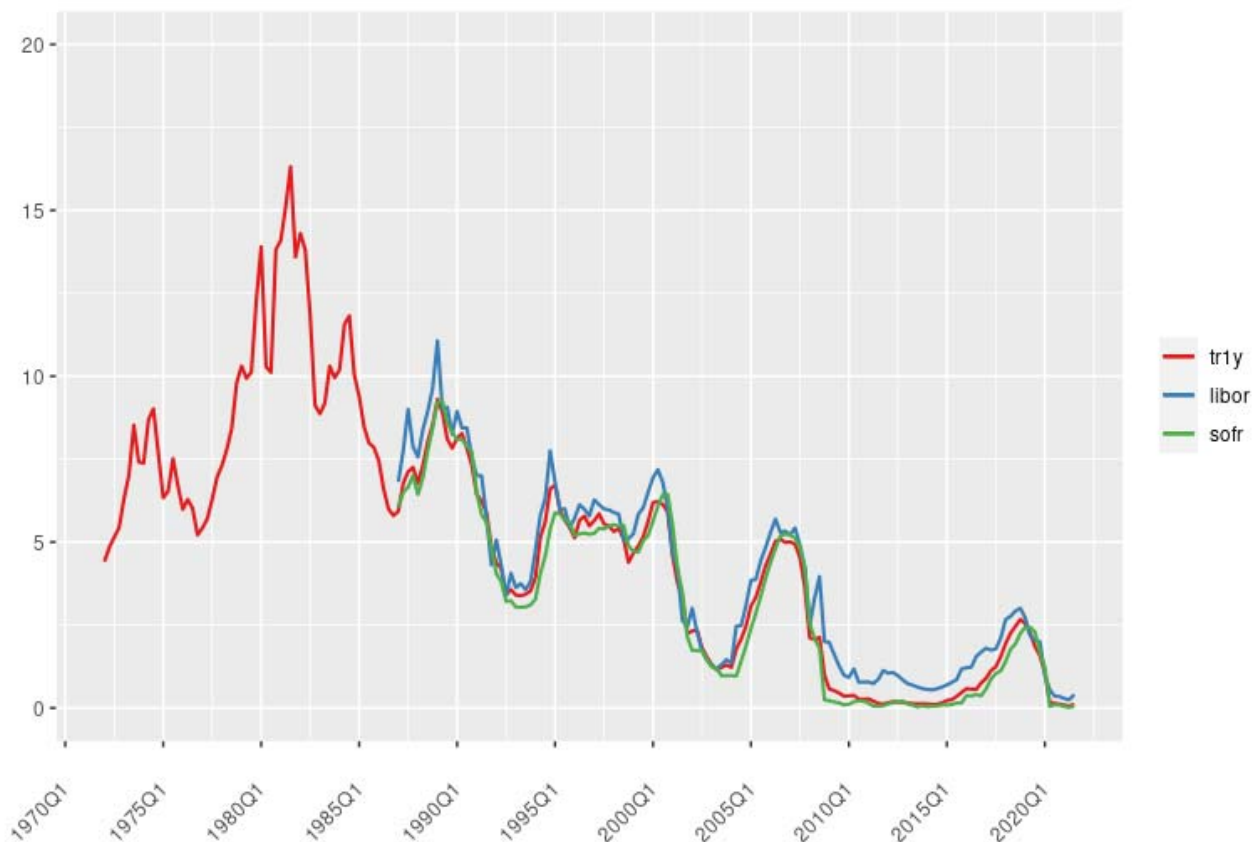


Figure 24 shows historical interest rate spreads, including the spread between 10-year and one-year CMT rates (tr10y\_s) and the spread between the 30-year FRM rate and the 10-year CMT rate (mr10y\_s). Both spreads are primarily positive with long cycles. Lower, negative spreads typically correspond with economic downturns, such as the downturn that occurred during the late 1970's through the early 1980's. Also note, the spread of the mortgage rate over the 10-year CMT rate is always positive, reflecting the premium for credit risk.

Both spreads turn sharply in the last three quarters.

Figure 24: Historical Interest Rate Spreads (%)



**B. House Price Appreciation Rates**

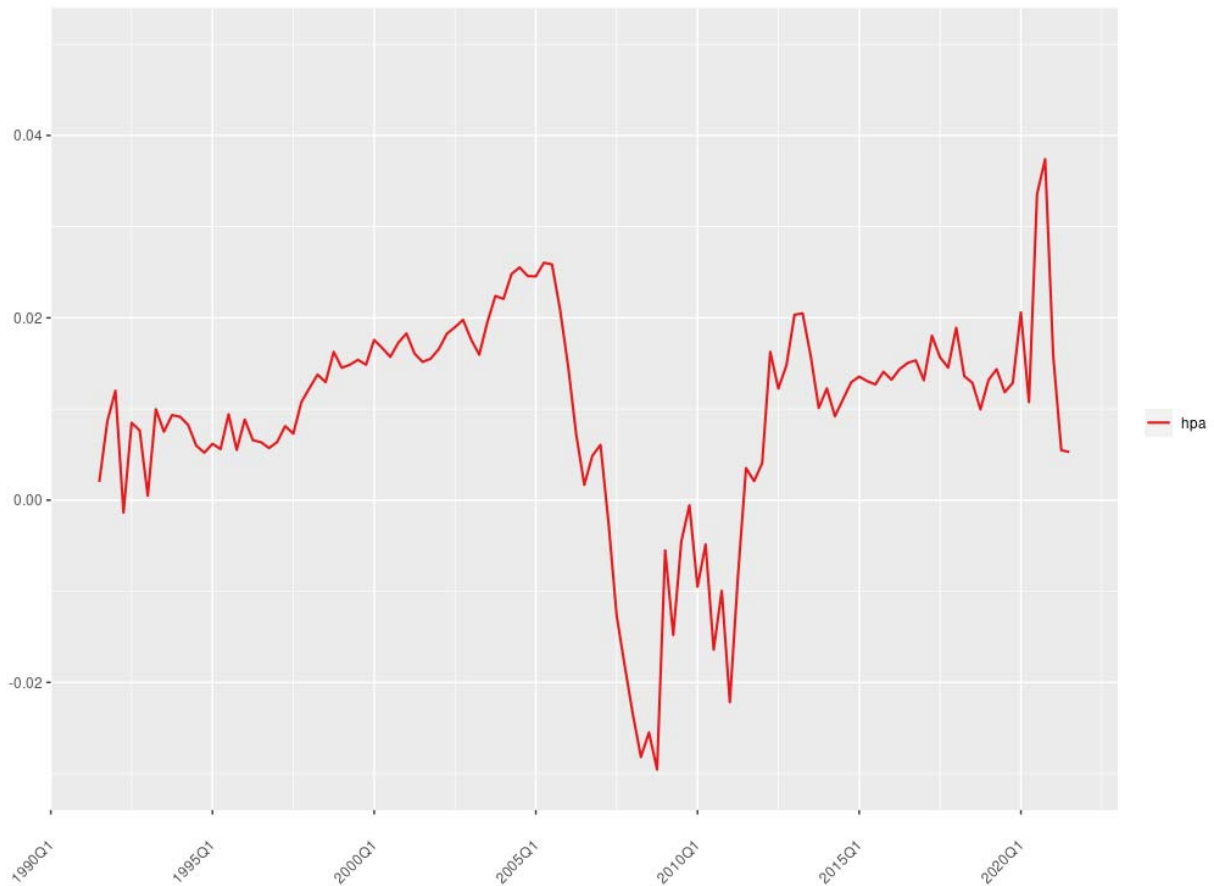
The national house price appreciation rate (HPA) is derived from the FHFA repeat sales house price indexes (HPIs) of purchase-only (PO) transactions. The PO HPI provides a reliable measure of housing market conditions, since it is based on repeat sales at market prices and does not use any appraised values.

The HPA series being modeled is defined as:

$$HPA_t = \ln\left(\frac{HPI_t}{HPI_{t-1}}\right) \quad (1)$$

Figure 25 shows the national quarterly HPA from the first quarter of calendar year 1991 to the third quarter of calendar year 2021. The long-term average quarterly HPA is approximately 0.87% (3.30% annual rate).

Figure 25: Historical National HPI and Quarterly HPA



The HPI increased steadily before 2004, and the quarterly appreciation rate was around 1.14%. Then house prices rose sharply starting in 2004. The average quarterly home-price appreciation rate was 1.88% during the subprime mortgage expansion period from 2004 to 2006, and reached its peak of 2.59% in 2005 Q2. After 2006, the average growth rate of house prices became negative until 2011, when appreciation returns to a positive value. Following an almost eight quarter period of a nearly flat appreciation rate, the first two quarters of the COVID-19 shutdowns showed a sharp decrease to nearly 0% appreciation, followed by historic home appreciation not seen since the sub-prime bubble. Low inventory, low interest rates, prohibitively high construction costs, and more remote work options are all contributing factors to this recent home appreciation.

Table 36 shows the quarterly HPA by selected historical time-periods.

Table 36: Average Quarterly HPA by Time Span

Period	Average Quarterly
1991 – 2003	1.15%
2004 – 2006	1.86%
2007 – 2010	-1.25%
2011 – 2019	1.15%
2020-2021-Q3	1.84%

### C. Confidence Indices

The Small Business NOI and CCI are confidence indices based on surveys conducted throughout the year by The Conference Board. These indexes are designed to provide a relative measure of how optimistic or pessimistic consumers and small business are regarding their expected financial situation. Both indices are based around 100 points where indicators above 100 signal relative optimism for the future of the economy, values below 100, relative pessimism. Figure 26 and Figure 27 show historical CCI and NOI, with noted sharp drops in confidence associated to the 2008 mortgage crisis and the beginning of the COVID-19 shutdowns. The most recent quarter shows an upturn in these indices as COVID-19 restrictions are lifted.

Figure 26 – Consumer Confidence Index

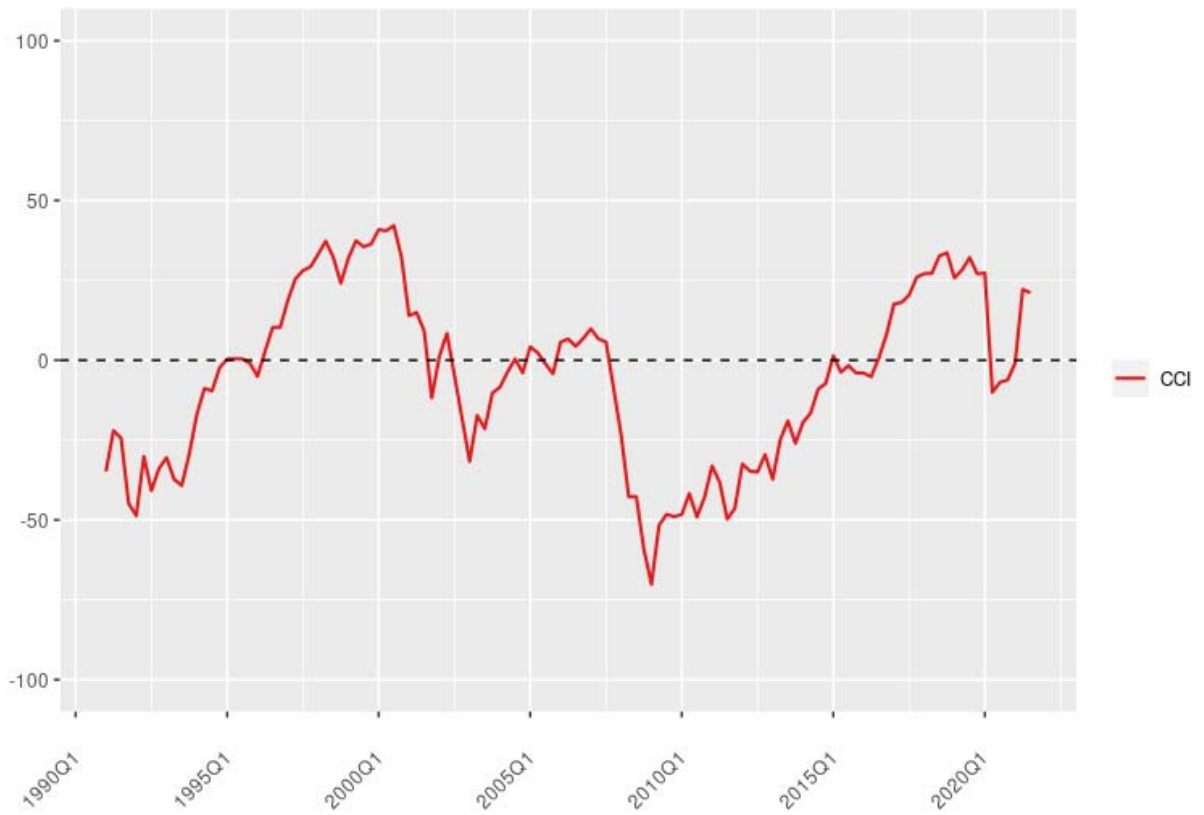


Figure 27 - Small Business Normalized Optimism Index

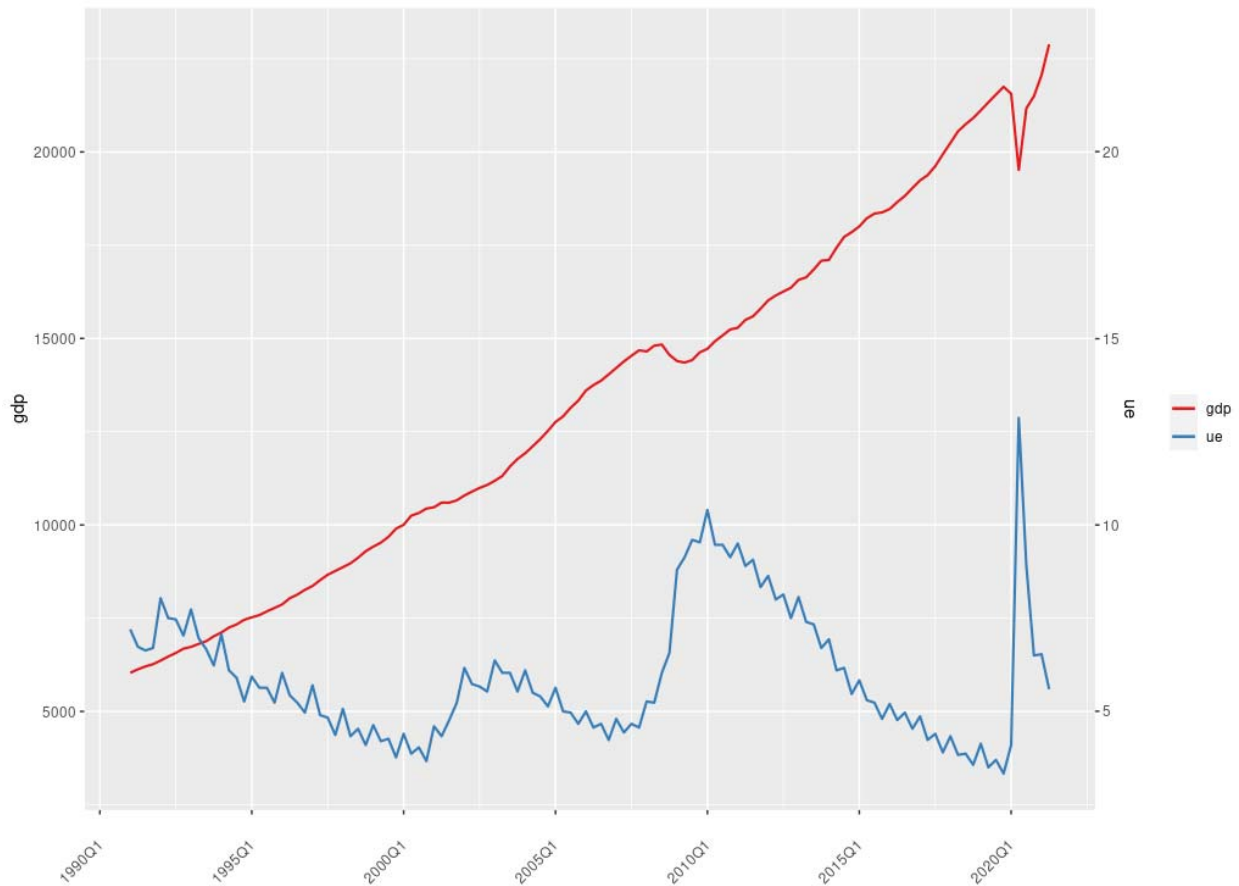


### Modeling Method

In financial econometrics and management understanding, predicting the dependence in the co-movements of these series is important when simulating a set of economic factors. This is illustrated in Figure 22, where interest rates track closely.

Long periods of high unemployment will lead to lower GDP. In Figure 28, we can see two obvious examples of this following the mortgage crisis in 2008 and again with the recent COVID-19 pandemic. The most recent quarters illustrate how lockdown restrictions lessened, unemployment dropped, and GDP again begins to increase.

Figure 28 - Unemployment vs. GDP



Volatilities will also move together across these series. High levels of economic instability and uncertainty will lead to volatility in these measures, affecting all economic indicators. A modeling method that accounts for these factors will lead to models that are more relevant.

Recognizing and accounting for these features through a multivariate model should lead to more accurate empirical models than working with separate univariate models.

For these reasons a multivariate General Auto Regressive Conditional Heteroscedasticity (GARCH) modeling approach was chosen.

Univariate GARCH models are typically specified as  $GARCH(p,q)$  where  $p$  is the auto regressive (AR) component of  $\sigma_t^2$ , and  $q$  is the auto regressive component of the error term. Multivariate GARCH models are defined similarly to a standard GARCH model, where the univariate term is replaced with a vector of terms. Mezrich (1995) and Shephard (1996) provide a more detailed explanation of these models.

There are a number of implementations of multivariate GARCH models. One such implementation, Dynamic Conditional Correlation (DCC) estimators, have the flexibility of univariate GARCH but avoid the complexity of conventional multivariate GARCH algorithms. Engle and Sheppard (2000) detail descriptions and examples of using a DCC models for time series analysis.

The 'rmgarch' package implemented with the Cran-R project was specifically used for this modeling effort, developed by Ghalanos (2019), and based off the methods described by Engle (2000).

### Data Transformation

The algorithms required to calculate maximum likelihood estimates in these families of models are prone to non-convergence. Variable scale, stationarity of the variables, and covariance within the variable vector set are often the underlying issue when dealing with non-convergence in these complex matrix calculations. Data transformation was performed on these variables to provide a more robust and consistent estimate.

Dickey-Fuller stationarity test were performed on all variables. GDP and HPA test as non-stationary. As a result, first difference transformations were applied to all variables to provide stationarity. Further scaling was required for index variables (*Ind*) using a log transformation:

$$Ind_{trans} = \ln(Ind + \sqrt{Ind^2 + 1}) \quad (1)$$

Table 37 below provides a description of each variable transformation.

### Model Specifications

Each variable is provided a univariate type specification, in a standard (p,q) format where p,q for the ARMA (mean) specification describes the number of autoregressive and moving average lags to include in the model, and (p,q) for the GARCH specification correspond to the autoregressive components and heteroskedastic components (auto regressive component of error term) respectively. See Table 37 for each variable specification.

*Table 37 – Model Variable Transformations and specifications*

VARIABLE	VARIABLE TRANSFORMATION	ARMA(P,Q)	GARCH(P,Q)	DISTRIBUTION
<b>SOFR</b>	First difference	(0,1)	(1,1)	Normal
<b>LIBOR</b>	First difference	(0,1)	(1,1)	Normal
<b>3-MONTH</b>	First difference	(0,1)	(1,1)	Normal
<b>6-MONTH</b>	First difference	(0,1)	(1,1)	Normal
<b>1-YEAR</b>	First difference	(1,0)	(1,1)	Normal
<b>10-YEAR</b>	First difference	(1,0)	(1,1)	Normal
<b>30-YEAR</b>	First difference	(1,0)	(1,1)	Normal

VARIABLE	VARIABLE TRANSFORMATION	ARMA(P,Q)	GARCH(P,Q)	DISTRIBUTION
<b>30-YEAR FRM</b>	First difference	(1,0)	(1,1)	Normal
<b>UNEMPLOYMENT</b>	First difference	(0,0)	(1,1)	Normal
<b>GDP</b>	First difference, log function transformation	(1,1)	(1,1)	Skewed generalized error
<b>HPI</b>	First difference, log function transformation	(1,1)	(1,0)	Skewed student-t
<b>NOI</b>	First difference, log function transformation	(0,0)	(0,1)	Normal
<b>CCI</b>	First difference, log function transformation	(0,0)	(0,1)	Normal

When fitting a DCC model, the dynamic correlation is fitted with an autoregressive parameter that is applied across all variables. This was set with a (p,q) value of (1,1), describing the correlation across all variables as one autoregressive and one moving average period. These parameters are then used in calculating the correlation matrix.

Table 38 provides all parameter estimates, where “mu” is the mean, “ar” represent the auto regressive and “ma” represent the moving average of the mean model.

Parameters “omega”, “alpha” and “beta” are the mean, autoregressive, and heteroskedastic parameters of the variance model.

Parameters “skew” and “shape” are estimates to account for specified skewed distributions (GDP and HPI).

Table 38 – Parameter Estimates

VARIABLE	ESTIMATE
TR1YR.MU	0.01724
TR1YR.MA1	0.71714
TR1YR.OMEGA	0.00036
TR1YR.ALPHA1	0.34207
TR1YR.BETA1	0.65693
TR3M.MU	-0.22537
TR3M.AR1	0.86119
TR3M.OMEGA	0.00032

VARIABLE	ESTIMATE
TR3M.ALPHA1	0.28101
TR3M.BETA1	0.71799
TR6M.MU	-0.48917
TR6M.AR1	0.98503
TR6M.OMEGA	0.00012
TR6M.ALPHA1	0.22764
TR6M.BETA1	0.77136
TR10YR.MU	1.77300
TR10YR.AR1	0.97010
TR10YR.OMEGA	0.03891
TR10YR.ALPHA1	0.16538
TR10YR.BETA1	0.45318
TR30YR.MU	2.01786
TR30YR.AR1	0.97998
TR30YR.OMEGA	0.06930
TR30YR.ALPHA1	0.27234
TR30YR.BETA1	0.20642
MR.MU	3.15043
MR.AR1	0.97400
MR.OMEGA	0.04476
MR.ALPHA1	0.36413
MR.BETA1	0.21683
UE.OMEGA	0.00632
UE.ALPHA1	0.00000
UE.BETA1	0.99900
GDP.MU	5.55453
GDP.AR1	-0.19473
GDP.MA1	0.28420
GDP.OMEGA	0.00895
GDP.ALPHA1	0.08965
GDP.BETA1	0.88556
GDP.SKEW	0.75925
GDP.SHAPE	0.50449
HPI.MU	1.15621
HPI.OMEGA	0.57897
HPI.ALPHA1	0.78772
HPI.SKEW	0.36901
NOI.MU	0.04268
NOI.AR1	0.03006
NOI.OMEGA	0.61594
NOI.ALPHA1	0.13486

VARIABLE	ESTIMATE
NOI.BETA1	0.74107
CCI.MU	0.46589
CCI.AR1	0.05837
CCI.OMEGA	0.12328
CCI.ALPHA1	0.00000
CCI.BETA1	0.99900
LIBOR.MU	0.43774
LIBOR.AR1	0.76301
LIBOR.OMEGA	0.03109
LIBOR.ALPHA1	0.94492
LIBOR.BETA1	0.05408
SOFR.MU	-0.26516
SOFR.AR1	0.94074
SOFR.OMEGA	0.02250
SOFR.ALPHA1	0.85242
SOFR.BETA1	0.14658

### COVID-19 Pandemic Considerations

The impact from the COVID-19 pandemic is noticeable and dramatic when analyzing these economic indicators. Dramatic, historic, and rapid changes to these economic measures provided additional challenges when fitting these models, and produced simulated results that were skewed and assumed to misrepresent historical data.

Because of the historic nature of this event, and its impact on the economy, it is unknown what the long-term impacts of this pandemic will have on the economy. Numerous research articles have been produced to estimate or predict these long-term impacts (Chudik, 2020; Malliet, 2020).

Based on this research, the current state of COVID-19 vaccine development, and an analysis of historical data, a randomized impact of the pandemic was applied.

As a result, two models were estimated, one basing estimates on pre-pandemic variables, and the second including the pandemic data. A continued impact of eighteen months to five years (six to 20 quarters) was applied randomly as a diminishing linear weight. The two model simulations were then combined using this weighting factor, where the COVID-19 simulations were given the most weight, and then slowly removing the COVID-19 impacts to the simulations over the randomized period of time, until the COVID-19 simulations were given no weight, and the pre-COVID-19 simulations all the weight.

## Simulation Generation

Model fit was performed through an iterative process, varying parameter specifications for both ARMA and GARCH model components.

Distributions were determined using standard distribution fitting techniques, including QQ-plots and Kolmogorov-Smirnov tests.

Further parameter selection and distribution adjustments were made based on comparative analysis of simulations to historical series, providing the most reasonable estimates and simulations possible.

One hundred simulations were generated for each of the economic variables. These variables were fully transformed back to the common form and scale as the original un-transformed versions.

## Interest Rate Simulations

Table 39 shows the summary statistics of the historical 1-year Treasury rates for two different periods as well as the simulated series. We can see that in the last 50 or more years, interest rates have had a much broader range as compared to the last 25 years.

*Table 39: Statistics for the 1-Year Treasury Rates*

STATISTICS	SINCE 1953	SINCE 1991	SIMULATIONS
95-PERCENTILE	10.29%	6.12%	7.53%
90-PERCENTILE	8.90%	5.66%	6.49%
50-PERCENTILE	4.57%	2.26%	2.83%
25-PERCENTILE	2.25%	0.46%	1.45%
10-PERCENTILE	0.36%	0.14%	0.59%
5-PERCENTILE	0.15%	0.12%	0.24%
MEAN	4.69%	2.72%	3.26%
MAX	16.31%	6.71%	11.45%
MIN	0.06%	0.06%	0.01%
VARIANCE	10.98%	4.81%	1.53%

Figure 29 shows density distributions, comparing the distribution of the historical CMT rates, historic sample used for simulations, and the distributions of all the simulations.

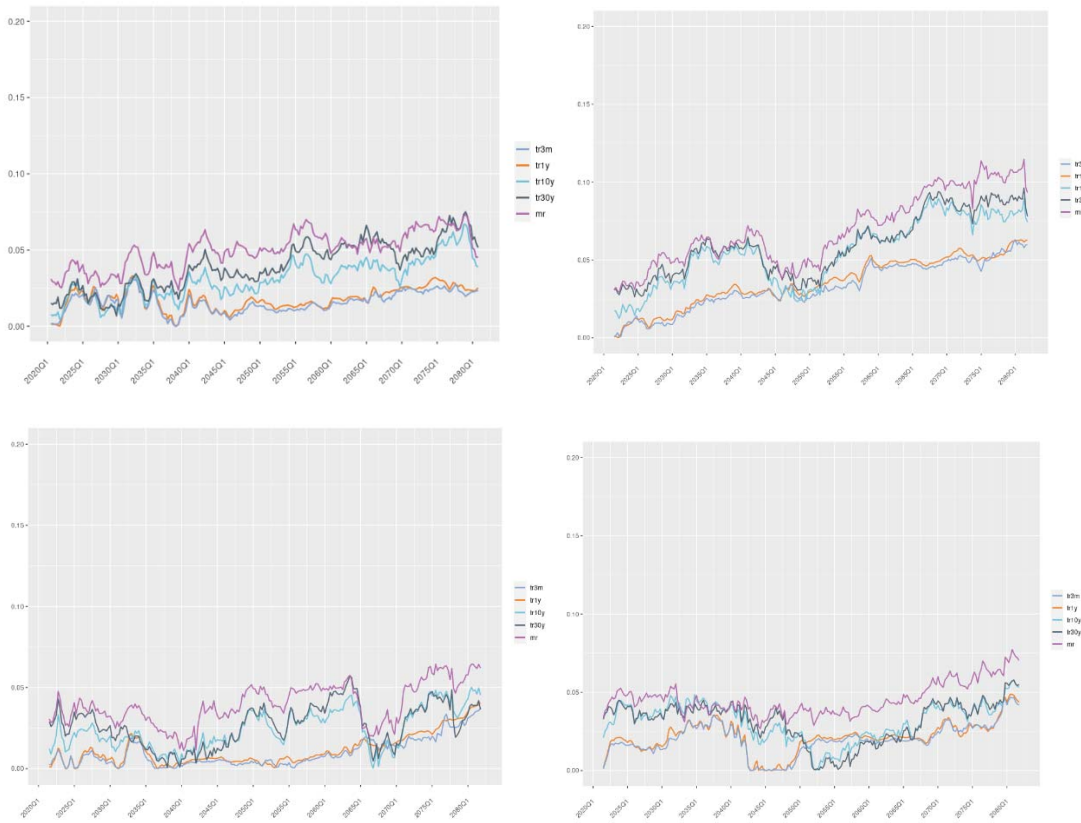
Figure 29 – 1 Year Treasury Rate Densities, Historical and Simulations



To avoid negative interest rates, a lower bound of 0.01 percent was applied to all the simulated future interest rates.

Figure 30 graphs one of the one-hundred simulations, illustrating the co-movements and correlations between these variables and how the multivariate modeling method accounts for these interdependencies.

Figure 30: Interest Rate Sample Simulations



## House Price Appreciation Rate (HPA)

### A. National HPA

The national HPA is calculated by first estimating and simulating HPI. From the HPI simulation, these simulations are then transformed using formula (1) to simulate HPA.

Table 40 provides comparison of simulated HPI average trends and the historical sample trends. The analysis show a significant spread between the series when comparing the largest and smallest trends, but when simulated trends are averaged across all series they are very close to the historical trend used in model fitting.

Table 40 – HPI Simulation Statistics

	SIMULATED SERIES			HISTORICAL
	Max trend	Min trend	Mean trend	Trend
HPI	2.9748	2.0057	2.3137	0.0571

## B. Geographic Dispersion

The MSA-level HPA forecasts were based on Moody's forecast of local and the national HPA forecasts. Specifically, at each time  $t$ , there is a dispersion ratio of HPAs between the  $i^{\text{th}}$  MSA or State level and the national forecast:

$$Disp_{i,t}^{Base} = HPA_{i,t}^{Base} / HPA_{national,t}^{Base} \quad (6)$$

This dispersion forecast under Moody's base case was preserved for all local house price forecasts under individual future economic paths. That is, for economic path  $j$ , the HPA of the  $i^{\text{th}}$  MSA at time  $t$  was computed as:

$$HPA_{i,t}^j = HPA_{national,t}^j * Disp_{i,t}^{Base} \quad (7)$$

This approach retains the relative current housing market cycle among different geographic locations and it allows us to capture the geographical concentration of FHA's current endorsement portfolio. This approach is also consistent with Moody's logic in creating local market HPA forecasts relative to the national HPA forecast under alternative economic scenario forecasts.<sup>3</sup>

We understand this approach is equivalent to assuming perfect correlation of dispersions among different locations across simulated national HPA paths, which creates systematic house price decreases during economic downturns and vice versa during booms. Due to Jensen's Inequality, this tends to generate a more conservative estimate of claim losses of the Fund.

## Unemployment Rate

### A. National Unemployment Rate

Table 41 provides statistics comparing series samples of unemployment rates to the simulated series.

Table 41 – Unemployment Historical and Simulation Statistics

STATISTICS	SINCE 1953	SINCE 1991	SIMULATIONS
95-PERCENTILE	9.13%	9.43%	10.22%
90-PERCENTILE	8.11%	8.77%	9.33%
50-PERCENTILE	5.57%	5.50%	5.98%
25-PERCENTILE	4.54%	4.65%	4.65%
10-PERCENTILE	3.70%	4.11%	3.98%
5-PERCENTILE	3.39%	3.84%	3.56%
MEAN	5.77%	5.92%	6.35%
MAX	12.87%	12.87%	15.95%

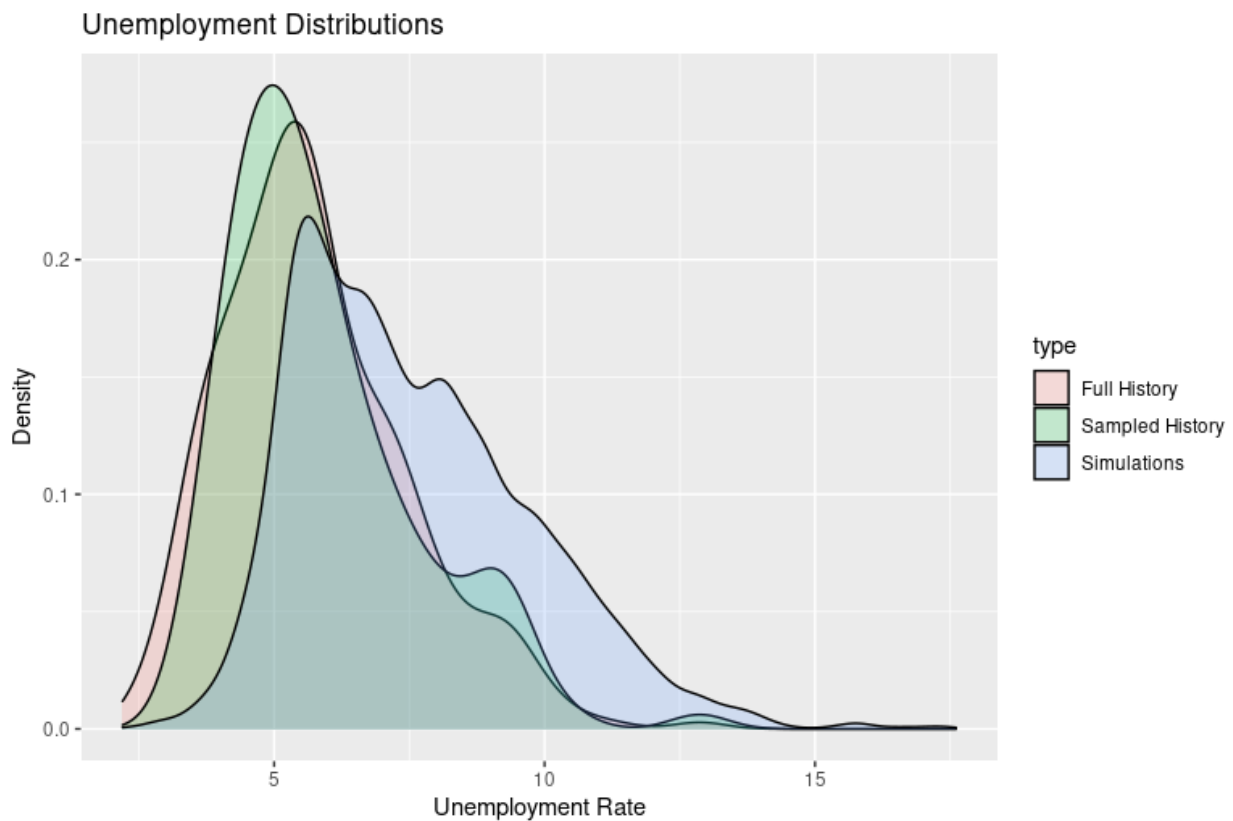
<sup>3</sup> The dispersion of each MSA remains constant among all alternative Moody's forecast scenarios.

<b>MIN</b>	2.47%	3.33%	1.53%
<b>VARIANCE</b>	2.97%	3.07%	1.74%

Based on historical statistics, the national unemployment rate limits were set at 20% maximum and a 2% minimum.

Figure 31 is a density plot comparison of the historical series and simulated sets.

Figure 31 - Unemployment Rate Densities Historical and Simulations



**B. Geographic Dispersion**

Following the same logic that we applied to the MSA-level HPA forecasts, we first obtained the dispersion of unemployment rates between the  $i^{th}$  MSA or State level and the national level from Moody’s July base-case forecast at each time  $t$ :

$$Disp_{i,t}^{Base} = ue_{i,t}^{Base} / ue_{national,t}^{Base} \tag{9}$$

This dispersion forecast was preserved for all local unemployment rate forecasts under each individual future economic path. That is, for economic path  $j$ , the unemployment rate of the  $i^{\text{th}}$  MSA at time  $t$  was computed as:

$$ue_{i,t}^j = ue_{national,t}^j * Disp_{i,t}^{Base} \quad (10)$$

For the simulation, we capped the unemployment rate at the local level at 30% with a floor at 1%.

### Gross Domestic Product

Table 42 provides statistics comparing the historical GDP series trend to simulated trends. The analysis show a fairly small spread between the series when comparing the largest and smallest trends, and when simulated trends are averaged across all series they are very close to the historical GDP trend used in model fitting.

Table 42 – GDP Simulation Statistics

	SIMULATED SERIES			HISTORICAL
	Max trend	Min trend	Mean trend	Trend
<b>GDP</b>	2.6507	1.7513	1.9984	2.8513

### Small Business Normalized Optimism Index/ Consumer Confidence Index

The Small Business NOI and CCI are based on a 100 point scale, where values under 100 represent less confidence in the economy, values over 100 indicate an increase in confidence.

Table 43 - Confidence Indices Statistics

	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED
	NOI	NOI	CCI	CCI
<b>MAX</b>	142.11	179.35	108.18	122.42
<b>MIN</b>	29.86	23.72	82.73	56.59
<b>MEAN</b>	94.38	98.41	98.15	107.79

Table 43 provides comparisons of range and means for both indices and the corresponding simulated data showing that the simulations provide reasonable ranges compared to historical data.

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## APPENDIX E: HECM CASH FLOW ANALYSIS

This appendix describes the calculation of the Cash Flow NPV. Future cash flow calculations are based on forecasted variables, such as HPI and interest rates, in addition to individual mortgage characteristics and borrower behavior assumptions. HECM cash flows are discounted according to the latest discount factors published by OMB.

### General Approach to Mortgage Termination Projections

HECM termination rates are projected for all future policy years for each active mortgage. The variables used in the projection are derived from mortgage characteristics and economic forecasts. Moody's October 2021 forecasts of interest rates and HPI are combined with the mortgage-level data to simulate the projected economic paths and create the necessary forecasted variables. MSA-level forecasts of HPI apply to mortgages in metropolitan areas; otherwise mortgages use the state-level HPI forecasts. Moody's house price forecasts are generated simultaneously with various macroeconomic variables.

For each mortgage during future policy years, the derived mortgage variables serve as independent variables to the multinomial logistic termination models described in Appendix B. The termination projections by claim type are then calculated to generate the probability of mortgage termination in a policy quarter by different modes of termination given that it survives to the end of the prior policy quarter. The HECM cash flow model uses these forecasted termination rates to project the cash flows associated with different termination events. Based on the specific characteristics of the mortgage, the probability of each termination is calculated. Then, a random number between 0 and 1 is generated, and based on this random draw a mortgage transition is determined. The projection process continues for each mortgage until the mortgage ends by termination or claim.

### Cash Flow Components

There are four major components of HECM cash flows:

1. MIP
2. claims
3. note holding expenses
4. recoveries on notes in inventory (after assignment)

Premiums consist of upfront and annual MIPs, which are inflows to the HECM program. Recoveries are the property recovery amount received by FHA at the time of note termination after assignment,

which is the minimum of the mortgage balance and the predicted net sales proceeds at termination. The recovery amount for refinance termination is always the mortgage balance. Claim Type 1 (CT1) payments are cash outflows paid to the lender when the net proceeds of a property sale are insufficient to cover the balance of the mortgage. Claim Type 2 (CT2) payments result from assignment of mortgages to HUD and note holding payments are additional outflows. Table 44 summarizes the HECM inflows and outflows.

Table 44: HECM Cash Flows

Cash Inflows	Cash Outflows
Upfront MIP	Claim Type 1 Payments
Annual MIP	Claim Type 2 Payments
Recoveries	Note Holding Expenses

### Mortgage Balance

The UPB is a key input to the cash flow calculations. In general, the UPB at a given time  $t$  is calculated as follows:

$$UPB_t = UPB_{t-1} + Cash\ Draw_t + Accruals_t$$

The UPB for each period  $t$  consists of the previous mortgage balance plus any new borrower cash draws and accruals. The accruals include interest, annual MIP, and servicing fees. Future draws for borrowers with a line of credit are estimated based on a model of historical cash flow draws as described in Appendix D. Otherwise, mortgages with a tenure plan use the cash draws associated with the tenure of the mortgage.

### Tax & Insurance Defaults

In ML 2011-01, FHA announced that a HECM with tax and insurance (T&I) delinquencies is considered due and payable, and therefore subject to foreclosure if the borrower does not comply with the repayment plan.<sup>4</sup> Through impacts on termination speeds and recovery rates, this ruling was intended to positively impact the economic value of the HECM program by providing an intervention that could reduce potential losses.

<sup>4</sup> Mortgagee Letter 2011-01, January 3, 2011 – “Home Equity Conversion Mortgage Property Charge Loss Mitigation.”

November 12, 2021

There were several major policy changes in Fiscal Year 2015 that may affect the T&I default experience. In ML 2015-09, FHA introduced the requirement and calculation of Life Expectancy Set-Aside (LESA), which is used for the payment of property taxes and hazard and flood insurance premiums. The LESA guidelines became effective on April 27, 2015. With this set-aside, HECM's with LESA will have fewer funds available for withdrawal, but there will be no T&I default before the life expectancy of the borrowers. Since this program has only five years of history and there is no origination data showing information related to LESA, we assume no effect of this LESA guideline due to limited information about mortgages impacted by this guideline. Once more origination data with LESAs become available, the potential performance impact of this policy will be re-evaluated.

For HECMs before assignment, FHA provided additional guidance on due and payable policies and the timing requirements in ML 2015-10<sup>5</sup> and ML 2015-11<sup>6</sup>. For HECMs after assignment, FHA currently does not foreclose on assigned mortgages that are in T&I default. In order to secure and maintain FHA's position on the lien of an assigned mortgage, FHA advances T&I payments on behalf of the borrower. FHA first advances funds from the borrower's available HECM funds. If no funds are available, FHA advances the tax payment and adds the payment amount to the UPB. These policies affect all existing books and future books.

For unassigned mortgages, if a mortgage goes to into default, the lender may provide a separate mortgage to the borrower to cover the T&I. If this occurs, once a mortgage becomes eligible for assignment, it will not be able to be assigned until the separate mortgage is satisfied.

For assigned mortgages, the T&I payments are treated as note holding expenses, a component of cash outflows, and added to the UPB. The projected T&I payments are projected separately as described in Appendix C.

## MIP

Upfront and annual MIP, along with recoveries, are the sources of FHA revenue from the HECM program. Borrowers typically finance the upfront MIP when taking out a HECM mortgage. Similarly, the recurring annual MIP is added to the balance of the mortgage. The upfront MIP is paid to FHA at the time of mortgage closing. It is equal to a stated percentage of the MCA. Typically, the upfront MIP is financed by the HECM lender. The upfront MIP is paid in full to FHA at the mortgage closing, and is a positive cash flow. The annual MIP is calculated as a percentage of the current mortgage balance.

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<sup>5</sup> Mortgagee Letter 2015-10, April 23, 2015 – "Home Equity Conversion Mortgage (HECM) Due and Payable Policies."

<sup>6</sup> Mortgagee Letter 2015-11, April 23, 2015 – "Loss Mitigation Guidance for Home Equity Conversion Mortgages (HECMs) in Default due to Unpaid Property Charges."

Before a mortgage is assigned, the annual MIP is assumed to be advanced by the lender, paid to FHA, and added to the accruing mortgage balance.

## Claims

Claims made by lenders consist of CT1 and CT2.

CT1 enters the HECM cash flows as payments to the lender when a property is sold and the net proceeds from the sale are not sufficient to cover the balance of the mortgage at termination. The CT1 payment for a mortgage that terminates without assignment is expressed as:

$$\text{Claim Type 1 Payment} = \text{maximum}(0, \text{UPB} - \text{Net Property Sales Price})$$

The net sales price of the property is:

$$\text{Net Property Sales Price} = \text{Estimated Property Sales Price} \times (1 - \text{sales expenses \%} - \text{other expenses \%})$$

The estimated property sale price is developed using models that incorporate the Maintenance Risk Adjustment (MRA). The MRA factors vary by period number and are determined such that the expected CT1 claim severity rate after applying the MRA to the projected home appraisal value is equal to the observed CT1 claim severity rate. The development of the MRA is incorporated in the CT1 and CT2 sales price models described in Appendix B.

Sales expenses are those required to conduct the actual sale, and other expenses are those incurred to manage the property until the sale. Sales and other expenses are estimated to be 24.7% of the sales price for REO claims based on home sale data provided by FHA. This is based on data related to the sale of over 9,000 FHA owned properties. The sales and other expenses include repair costs, taxes, M&O (Other), and sales expenses.

Lenders can assign a mortgage to FHA when the UPB reaches 98% of the MCA. A CT2 occurs when FHA acquires the note resulting in a cash outflow (the acquisition cost) which is the mortgage balance (up to the MCA). The ultimate net losses from CT2 depends on two components: the note holding expenses after assignment and recoveries from assigned notes.

FHA imposes a set of requirements that, if any of them are not met, makes the HECM ineligible for assignment even when UPB reaches 98% of the MCA. We project the probability of assignment based on historical data by the number of quarters the mortgage has been eligible for assignment as follows:

Table 45: Probability of Mortgage Assignment

Number of Quarters Since Eligible for Assignment	Probability of Assignment
1	15%
2	30%
3	15%
4	9%
5	5%
6	3%
7 – 8	2%
9+	1%

This results in approximately a 40% probability that the mortgage is assigned within the first two years it becomes eligible, and a small probability it is assigned after the first two years of eligibility.

#### Note Holding Expenses After Assignment

The note holding cash outflows include the additional cash draws by the borrower and property taxes FHA paid for those borrowers who default on their T&I payments during their assignment period. Additional cash draws by the borrowers can occur under the contract after FHA takes ownership of the note only if the total cash drawn by the borrower has not reached the maximum PL upon the assignment date.

#### Recoveries from Assigned Mortgages

At note termination for an assigned mortgage, the HECM is due and payable to FHA. The timing of mortgage terminations after assignment (when UPB reaches 98% of MCA) is projected with the termination model described in Appendix B. The amount of recovery of assigned mortgages at termination, can be expressed as:

Recovery Amount =

$$\begin{matrix} \text{minimum (UPB, Net Property Sales Price)} & \text{if terminated with death or move out} \\ \text{UPB} & \text{if terminated with refinance} \end{matrix}$$

where the net sales price of the property is:

$$\text{Net Property Sales Price} = \text{Estimated Property Sales Price} \times (1 - \text{sales expenses \%} - \text{other expenses \%})$$

### Net Future Cash Flows

The Cash Flow NPV for the HECM book of business is computed by summing the individual components as they occur over time:

$$\text{Net Cash Flow}_t = \text{Annual Premiums}_t + \text{Recoveries}_t - \text{Claim Type 1}_t - \text{Claim Type 2}_t - \text{Note Holding Expenses}_t$$

### Discount Factors

The discount factors applied were provided by FHA and reflect the most recent U.S. Treasury yield curve, which captures the Federal government's cost of capital in raising funds. These factors reflect the capital market's expectation of the consolidated interest risk of U.S. Treasury securities. Pinnacle has relied on FHA for the discount factors and has not performed an independent analysis of the appropriateness of the discount factors. Our simulations aggregate each future quarter's cash flows, which are treated as being received at the end of the quarter.

## APPENDIX F: REVIEW OF HUD ANALYSIS OF ECONOMIC NET WORTH, COMPARISON OF HUD AND PINNACLE MODELS, AND ASSESSMENT OF VULNERABILITIES

Appendix F presents a high-level review of HUD models developed to project Economic Net Worth, compares the models developed by HUD with the models developed by Pinnacle, and assesses the vulnerabilities of the models developed. We have also identified potential areas of future research based on this assessment.

Deliverable 5 of the Actuarial Report states:

***Deliverable 5: To promote transparency of the Studies' assessments, the Studies should identify methodological vulnerabilities that may occur in its actuarial models or in HUD's analyses of Economic Net Worth. This discussion should evaluate the scope and scale of such vulnerabilities in creating possible forecast risk and suggest possible lines of research in these areas. The Studies shall assess and comment upon HUD's own models that estimate Economic Net Worth for methodological vulnerabilities and compare HUD's methodologies with those in the Studies.***

There are several different aspects of forecast risk that can arise in the projection of Economic Net Worth, including:

- Process risk— actual results vary from projected results due to variability in the mortgage insurance process
- Parameter risk— the uncertainty related to the parameters selected for a given model
- Specification risk— the uncertainty related to the type of model that is selected for a forecast

The following discussion comments on these various types of forecast risk.

### HECM Budget Model Commentary

Summit-Milliman (S-M) has developed a series of models consisting of their HECM Model Schema.

## Model Schema

The HECM Budget Model Schema consists of six different modules:

- Volume Demand
- Home Price Projection
- Unpaid Principal Balance Projection
- Claim & Recovery
- Termination
- Insurance Cash Flow

The Volume Demand Module is used to forecast FHA's endorsement volumes for future cohorts. This model only applies to the budget formulation and not the Liability of Loan Guarantee (LLG) calculation. The Home Price Projection Module is used to forecast property values, and is used to estimate the home price at claim or termination of a HECM. The Unpaid Principal Balance Projection Module estimates the future unpaid loan balance for each loan.

There are multiple components of the Claim & Recovery Module. Claim probability modules use a logistic regression to estimate the probability of CT1 versus NCLM termination. A separate logistic regression model estimates the probability of CT2 conveyance versus payoff termination. The recovery estimation models are used to estimate sales price at claim or termination. The CT1 and CT2 sales price model is developed using linear regression. The CT1 and CT2 sales expense assumption is developed based on historical expenses as a percentage of the home sales price.

The Termination Module consists of logistic models for separate termination types as part of the multinomial logistic model. Probabilities are estimated for each type (mortality termination, refinance termination and other termination), and a weighted average is calculated to determine the overall likelihood of termination. As with the Stage 1 models for the HUD Forward assessment, this required the assumption of Independent Irrelevant Alternatives (IIA). This assumption is a candidate for future research and testing. HUD also assumed a waterfall pattern to the non-mortality terminations, which is reasonable based on the available data. Again, this could be a candidate for future research as more data becomes available.

The four types of terminations are the mortality termination, refinance termination, tax and insurance default termination, and the mobility termination. S-M has combined the Mobility termination and the Tax and Insurance Default termination into an all Other termination model. Mortality tables were used to determine mortality terminations separately by gender and age. A time lag between death and

termination of the loan regardless of claim type is also applied based on study of the data. This is a reasonable approach given the data available.

Finally, the sixth module is the Insurance Cash Flow Module. Here, claim, premium, cash draw, and recovery inflows and outflows are projected and weighed using the different termination probabilities generated in the previously described models to produce the expected cash flows. This analysis is completed at the individual loan level. Once the projected cash flows are determined, they are discounted to present value to arrive at the final Cash Flow NPV estimates for the portfolio.

S-M uses an 80% training and 20% validation split of the data for model development. Also, S-M tested actual versus expected results from their models and evaluated C-Statistics, which is reasonable. S-M also reviewed the Gini statistic for some of the models.

S-M identified limitations of the HUD data which in some cases make it difficult to determine with certainty how a HECM terminates. As a result, S-M grouped several causes of termination together. This could be a source of vulnerability in this analysis. However, due to these data limitations, S-M applied a variety of techniques, such as identifying variable interactions, using industry mortality tables, and classifying data into various groups of termination types to maximize the value of the data available.

There have been several policy changes made to the HECM program in recent years, but it is not clear if or how well they are reflected in the HUD data. This is both a possible source of vulnerability and an area for future research. S-M employs methodologies to assess and help ensure data quality, including model testing/validation, and input/assumption consistency and sensitivity testing. These approaches are reasonable. Also, S-M HECM code directly pulls the Moody's and President's Economic Assumption inputs from the forward model development. This improves consistency and efficiency of the process, while reducing risk of error.

From the prior analysis, S-M implemented several model changes.

- TMOD code has been updated to ensure consistency with FHA data updates, to make sure cash draws are consistent with FHA assumptions, and to ensure as variable creation is accurate.
- S-M made several updates to the splines based on a review of updated data.

Finally, S-M evaluated potential impacts on the HECM model results due to COVID-19. Initially, interim adjustments were made for potential borrower behavior changes including increased mortality rates, increased T&I defaults, and increased cash draws. These changes had very small effects on the models

themselves. In addition, as recent data has emerged, S-M noted that they did not actually see changes in portfolio composition or borrower behavior. Also, they felt that any changes to mortality rates are too uncertain at this point to adjust. Therefore, no changes were made to the HECM models due to potential COVID-19 impacts. This is reasonable based on the information available.

Following are additional potential sources of vulnerabilities and future research.

- Sensitivity tests performed on HPA and interest rate factors assumed independence of the factors. To the extent that these factors are not independent, this will affect the resulting Cash Flow NPV sensitivity.
- A potential area for future research is testing the two-year lookback for variables that use that period of time as they did for Return on Properties.
- S-M selected the 2006 cohort due to volume and seasoning of data for performing back-testing of their model results. While this is not unreasonable, this could be a potential source of vulnerability if the results would change significantly by using different cohort years for back-testing. S-M also noted that most results within one coefficient of variation of the model's point estimate for recent years on a number of variables. S-M provided some rationale for variables outside these deviations.

### Pinnacle HECM Budget Model Commentary

The following illustrates some of the similarities and differences in methodologies for the HECM model development between the Pinnacle analysis and the analysis performed by S-M.

Similar to the Pinnacle forward model approach, mortgage-level transition (frequency) and loss severity models were developed for HECM. The models were developed on mortgage level data, as was done by S-M. The Pinnacle models were built using a training/validation approach, similar to S-M's methodology. To validate the performance of the models, Pinnacle compared the actual to predicted results: the predicted probability of each transition for the logistic models and the expected sales price for each sales price model. Deciles were used for this purpose. This same validation approach was used for the Cash Draw models.

The primary vulnerability in the models is the same general vulnerability in developing predictive models: the extent to which historical patterns between target and projections are indeed predictive. Pinnacle has endeavored to address this potential vulnerability through a training and validation construct. We split the data into training and validation sets, similar to the approach that S-M used,

which allowed us to build the model on the training set and then determine how well it generalizes to a different dataset with the validation.

## Model Schema

The flow of the models used to determine the disposition of a HECM (the Termination Models) is as follows. There are many similarities to the HECM Budget Model Schema defined for the S-M analysis.

- Binomial logistic models were constructed to determine the probability of refinance or non-mortality termination (“other”) for a living borrower. If neither event happens, the loan continues.
- If the loan is not assigned and UPB is greater than or equal to 98%, Pinnacle simulates assignment based on assignment likelihoods. If the loan is assigned, then a CT2a status is applied and a CT2 loss occurs.
- If the loan does not terminate and is not assigned, then Pinnacle determines if any borrowers die based on mortality tables.
- If mortality occurs, then run-off probabilities are used to determine if the loan terminates.
- If there is a non-mortality termination, there are two possible paths:
  - Assigned loans use a CT2c model to determine the probability the loan ends up in conveyance (CT2c termination) or repayment (CT2p termination).
  - Non-assigned loans use a CT1 model to determine if the loan is a CT1 termination or no claim (NClm termination).
- Also, Pinnacle has developed CT1 and CT2c sales price models to estimate the sale price of the home and ultimately the potential loss to HUD.

The Cash Flow Draw Projection Models are used to estimate the future unscheduled cash draws associated with mortgages with a line of credit. This model is a binomial model to estimate likelihood of cash draw occurring in a period. If the model determines a cash draw occurs, then two separate logistic models are used to determine if the cash draw is a full draw. A GLM is then used to estimate the amount of the cash draw if it is not a full draw. S-M incorporates cash draws in their calculation, but does not develop models for cash draws. Pinnacle also develops a T&I default model which S-M also incorporates into the other termination model.

Finally, the Cash Flow Analysis is completed. Based on specific characteristics of the mortgage, the probability of each termination is calculated. The derived mortgage variables are independent variables to the multinomial logistic termination models in the Base Termination Model. A random number is generated and used in comparison to the model probabilities to determine the projected mortgage transition. This projection process continues for each mortgage until the mortgage ends by termination or claim.

The Net Cash Flow is defined as

$$\text{Net Cash Flow}_t = \text{Annual Premiums}_t + \text{Recoveries}_t - \text{Claim Type 1}_t - \text{Claim Type 2}_t - \text{Note Holding Expenses}_t$$

Annual Premiums are defined to include both Upfront MIP and Annual MIP. Note Holding Expenses include post-assignment cash draws and payments made by FHA borrowers who default on their T&I payments during their assignment period.

This is consistent with the HUD formula which is

$$\text{Net Cash Flow} = \text{Upfront Premium} + \text{Annual Premium} - \text{CT1} - \text{CT2} - \text{Post-assignment Cash Draws} + \text{Recovery} - \text{Post-Conveyance Expense}$$

To bring the cash flows to present value, Pinnacle used discount factors provided by FHA.

Cash Flow projections were generated for the OMB Economic Assumptions, 10 Moody's scenarios and 100 randomly generated stochastic simulations of key economic variables. The projections were used to develop a range of reasonable Cash Flow NPV projections. S-M and Pinnacle utilized Moody's data on a state and MSA level when possible to provide for a greater reflection of differences in home prices, etc. across the country.

## Simulation

Pinnacle ultimately utilized 100 economic scenarios generated by stochastic simulation to determine the range of cash flow NPV estimates. The HUD process used 10,000 simulations of key target variables using a Monte Carlo approach. This represents a key difference in the development of the range of results.

Pinnacle used ARMA and GARCH models to simulate various interest rates, HPA, unemployment rates, and GDP. Akaike Information Criterion (AIC) and/or Pearson's Goodness-of-Fit test were used to determine best fitting time series models to include in the simulation.

## APPENDIX G: SUMMARY OF HISTORICAL AND PROJECTED CLAIM RATES AND LOSS SEVERITIES

The following incremental annual summaries are shown by cohort for Claim Type 1 and Claim Type 2.

1. **Claim Rate**: number of claims divided by the number of originations for the cohort
2. **Loss Severity**: Net loss paid divided by the MCA for the cohort







