

MSCI Agency Credit Risk Transfer (CRT) Models

Yihai Yu

September 2019



CONTENTS

1 Summary 1

2 A Brief History of Mortgage Credit 3

3 Agency Credit Risk Transfer Deal Structure 5

4 Loan Default Model 6

5 Loss Severity Model 17

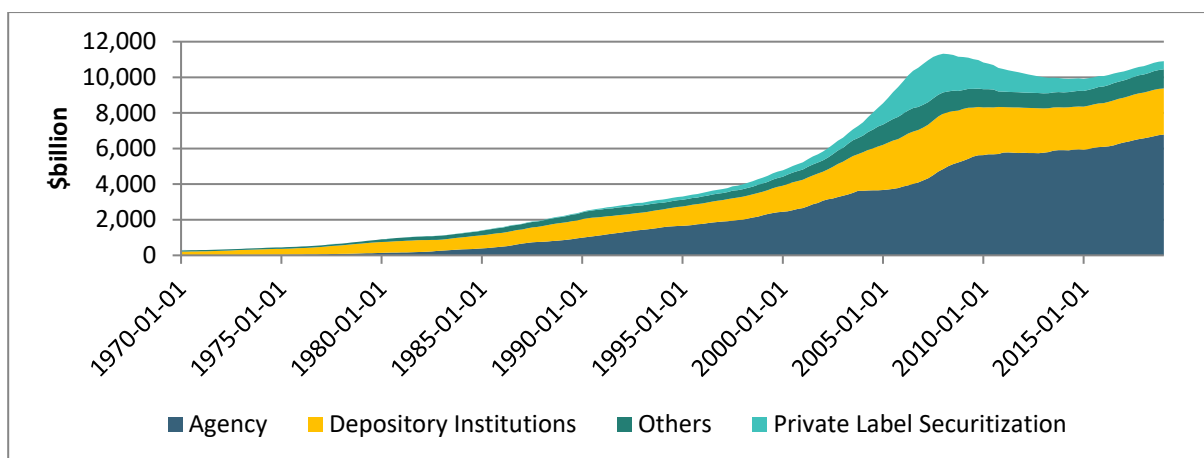
6 Prepayment Model 25

1 Summary

The majority of mortgages in the U.S. are securitized by Fannie Mae and Freddie Mac (the Enterprises), who essentially provide a credit guarantee to investors on these mortgage-backed securities (MBS). As a result, the Enterprises are exposed to substantial mortgage credit risk, i.e., the Enterprises have to make timely payments to investors when borrowers fail to meet their debt obligations. The traditional forms of mortgage credit management by the Enterprises include guarantee fees, private mortgage insurance (PMI), underwriting standards, representations and warranties, and equity capital. The 2008 financial crisis led to the conservatorship of the two Enterprises, as the credit losses exceeded the capacity of the Enterprises. To more effectively manage the Enterprises' mortgage credit exposure, the Enterprises have undertaken various reforms. One of the critical initiatives is the Credit Risk Transfer (CRT) program since 2013, with the goal to shift mortgage credit risk from the Enterprises and taxpayers (as the conservatorship is still in place after the takeover more than ten years ago) to private investors.

Exhibit 1 shows the historical outstanding mortgage composition by holders. "Agency" includes Fannie Mae, Freddie Mac, and Ginnie Mae; "Depository Institutions" are responsible for the unsecuritized mortgages; "Others" includes less significant financial institutions, such as life insurance companies and smaller government agencies; "Private Label Securitization" represents mortgages securitized in private mortgage conduits. Currently, more than 60% of the outstanding mortgages are held by the agencies. The increase of the agencies' share was enormous as private-label MBS issuance ground to a halt after 2008.

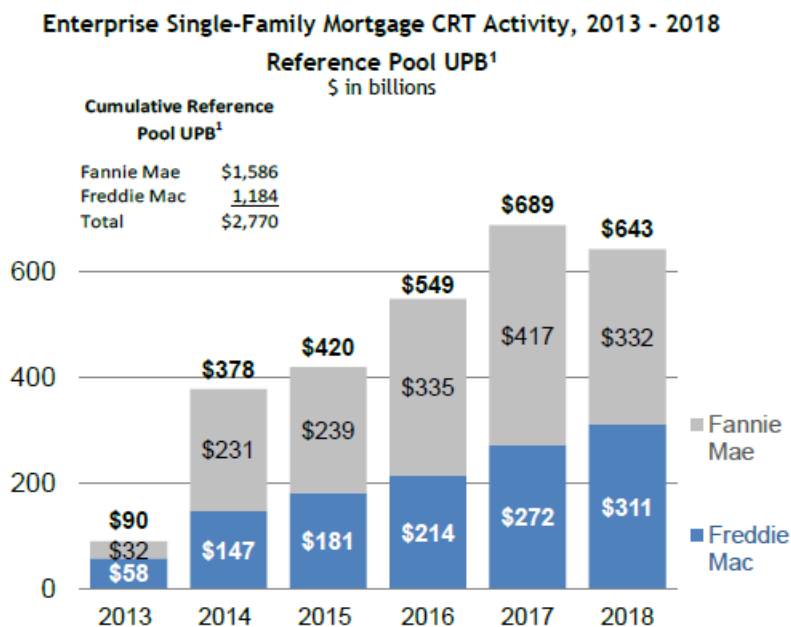
Exhibit 1: Historical outstanding mortgages by different entities



Source: Federal Reserve

The inaugural CRT deal (STACR-2013-DN1) was issued by Freddie Mac in July 2013, with a \$500 million note size, which effectively offloaded the mortgage credit risk of more than \$18 billion loans from Freddie Mac's guarantee book. The Enterprises' CRT programs have proven to be very successful over the past six years. Exhibit 2 shows that the Enterprises have transferred the credit risk of cumulatively almost \$2.8 trillion mortgages to private investors. The deal structures have also been evolving to attract private capital and offload the residual risk. For instance, loss calculation has evolved from a fixed severity schedule to actual loss; HARP and modified loans risks are now also transferred in separate deals; legal final maturity is extended to 30 years; a trust legal structure was introduced, replacing the form of unsecured debt; and so on and so forth. The Enterprises have also initiated various additional risk transfer programs, such as lender risk-sharing and reinsurance. For a comprehensive review, the author encourages readers to refer to the quarterly FHFA Credit Risk Transfer Progress Report.

Exhibit 2: Historical agency CRT activities



Source: Excerpt from the FHFA Credit Risk Transfer status report (4th Quarter 2018)

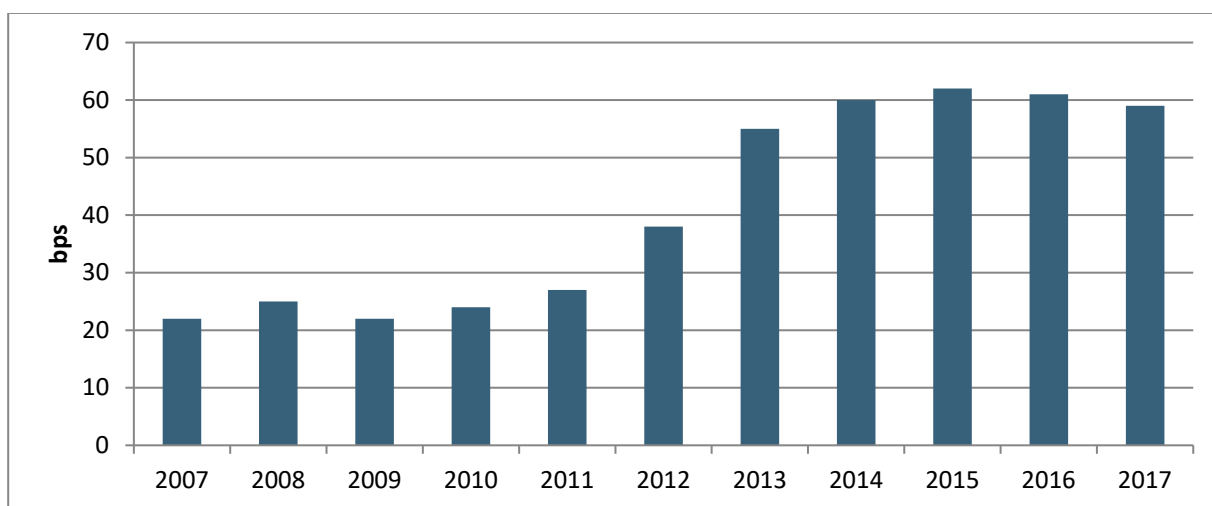
To facilitate these capital market transactions, Freddie Mac and Fannie Mae started to release loan-level credit performance data in early 2013. The Enterprises have disclosed about 20 years of monthly credit performance data on almost 50 million loans, with a detailed voluntary prepayment history, delinquency and foreclosure status data, as well as an actual loss breakdown. This rich dataset has enabled more advanced mortgage credit modeling. This paper focuses on the model insight extracted from this dataset and provides details of the MSCI CRT model.

2 A Brief History of Mortgage Credit

Historically, mortgage credit risk is mostly borne by four major types of players: banks, private-label MBS investors, mortgage insurance companies, and government agencies (Fannie Mae, Freddie Mac, ...).

- The largest component of mortgage credit is government agencies, of which Fannie Mae and Freddie Mac are the most dominant players, as shown in Exhibit 1. The Enterprises charge borrowers/lenders guarantee fees to cover future credit loss, a small administrative fee (as well as a 10-bp payroll tax cut funding charge currently), and a potential profit.
- Unsecuritized mortgages sit in the depository institutions' portfolio. The institutions bear the mortgage risk holistically, including both prepayment and credit risks;
- Private-label MBS securitizes mortgages into a certain capital structure, with the lowest tranche investors bearing the highest credit risk. The 2008 financial crisis has largely dried up this venue;
- Mortgage insurance companies receive premium from either lenders or borrowers. In exchange, the insurance company will shoulder the loss incurred by the loan default. Federal Housing Administration (FHA), U.S. Department of Veterans Affairs (VA), U.S. Department of Agriculture's Rural Development (RD), and HUD's Office of Public and Indian Housing (PIH) underwrite mortgage insurance for the Ginnie Mae loans.
- Various forms of bond insurance also transfer the mortgage credit risk to investors.

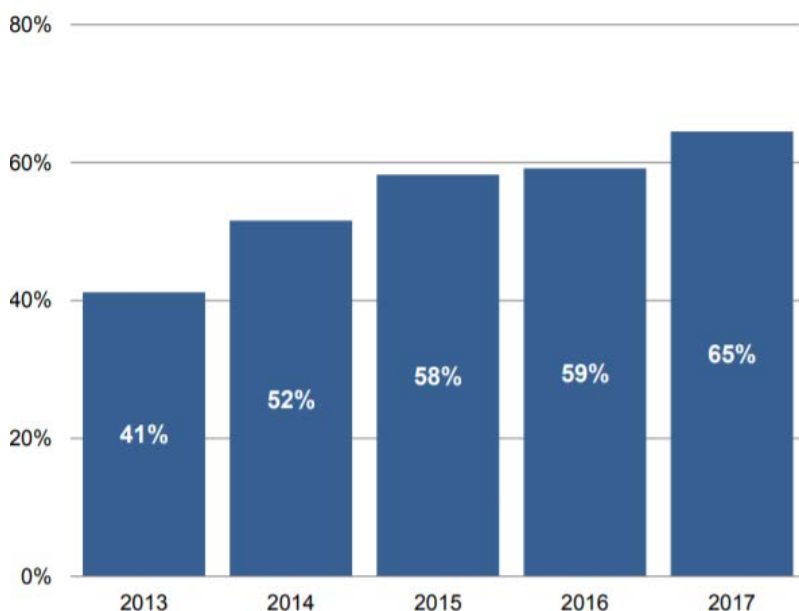
Exhibit 3: Historical g-fee rose significantly since financial crisis



Source: FHFA

Since the housing bubble burst in 2008, Fannie Mae and Freddie Mac experienced enormous mortgage credit loss. Both of the agencies were taken into conservatorship in September 2008. The U.S. Congress urged the housing industry and regulators to reform the U.S. housing financing system. The Federal Housing Finance Agency (FHFA), as the regulator of Fannie Mae and Freddie Mac, started the initiative of mortgage credit risk sharing, as outlined in the FHFA Conservatorship Scorecard.¹ Currently, the credit risk of more than 65% of the newly originated loans, acquired by the Enterprises, is transferred to private investors. The remaining loans, such as the ones with a much more aggressive amortizing schedule, generally pose much less credit risk and provide much better credit protection compared to the more dominant conventional 30-year fixed rate mortgages.

Exhibit 4: The Enterprises' Single-Family Loans Targeted for CRT (as a Percent of Total Acquisitions)



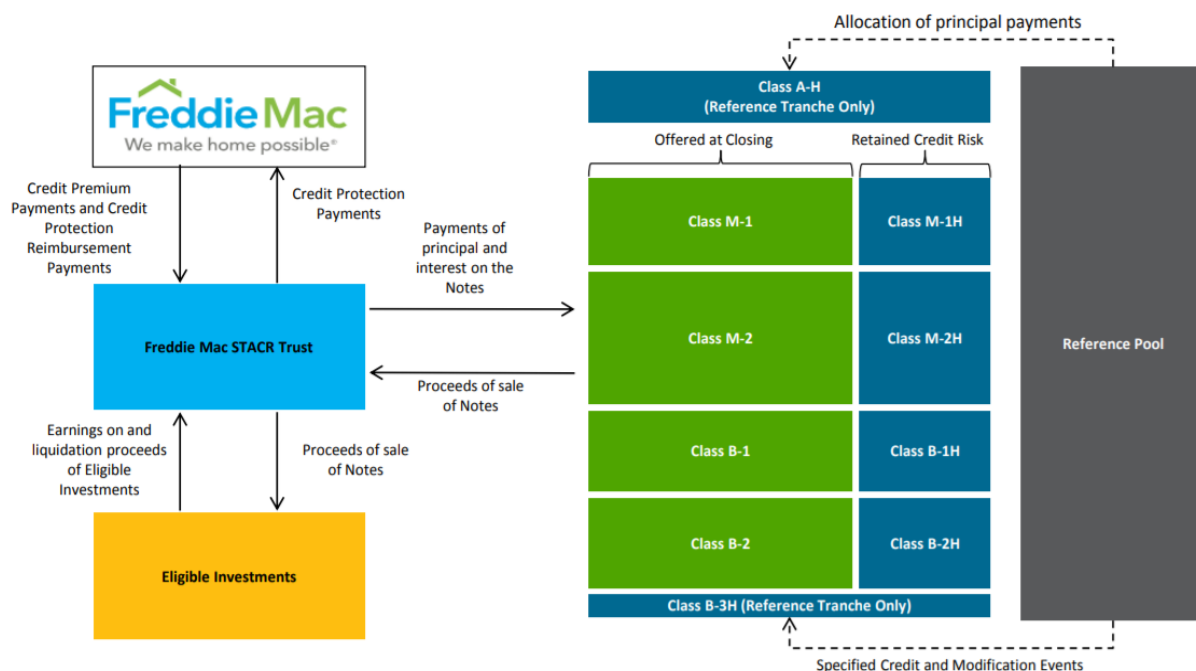
Source: Excerpt from the FHFA Credit Risk Transfer status report (4th Quarter 2018)

¹ [FHFA Outlines 2013 Goals for Fannie Mae and Freddie Mac](#)

3 Agency Credit Risk Transfer Deal Structure

Agency CRT deals are uncapped LIBOR-based floaters. Exhibit 5 shows the typical capital structure of a CRT deal. The “Reference Pool” contains the original mortgages. The tranches denoted by blue are effectively held by the GSE’s. If all credit performance testing triggers pass, the principal is allocated pro rata between senior and subordinate classes, with sequential pay among subordinate classes. When any trigger fails, the principal is allocated sequentially from senior to subordinate classes. The loss is allocated reversely according to the senior/subordinate deal structure and loss type. The capital structure details can be accessed via GSE’s deal prospectus.^{2 3} The next three sections focus on how the MSCI CRT model deals with the collateral’s credit and prepayment projection, which are inputs into the deterministic cash flow waterfall model for CRT deals.

Exhibit 5: CRT capital structure illustration with a sample Freddie Mac STACR deal



Source: Excerpt from Freddie Mac STACR

² Fannie Mae [Connecticut Avenue Securities \(CAS\)](#)

³ Freddie Mac [Structured Agency Credit Risk \(STACR\)](#)

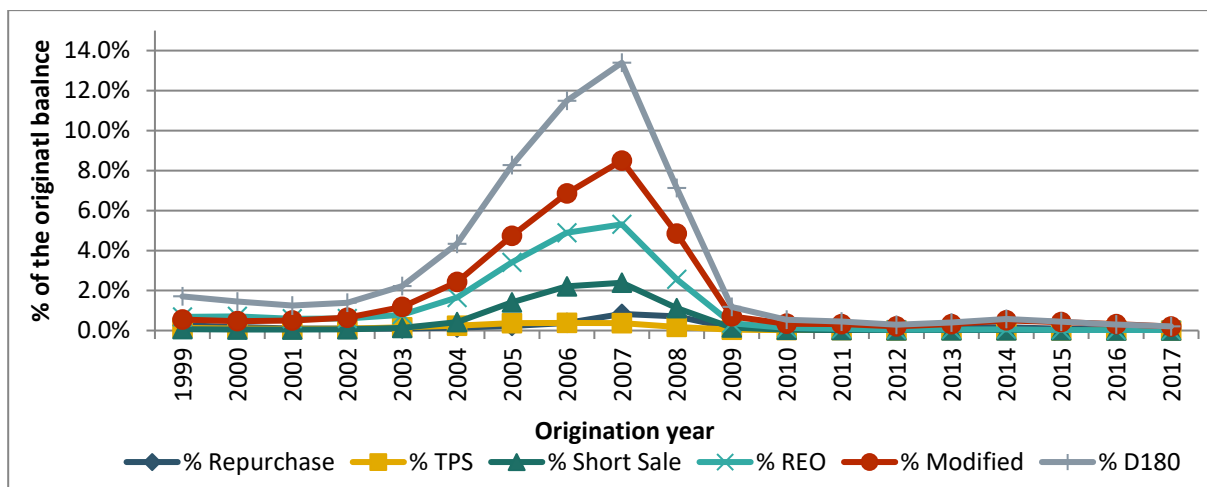
4 Loan Default Model

Since March 2013, the Enterprises have released 20 years of loan-level mortgage credit performance. This rich dataset has enabled modelers and researchers to gain unprecedented insights into U.S. mortgage borrowers' behavior under different economic environments, as well as more accurate model calibration.

Before we dive into the details of the loan default model, we need to have a more precise definition of "loan default." At a high level, there are three types of credit events from the CRT deal loss structure's perspective: 180-day delinquent, modification, and property disposition/default. We break the credit event into more granular types:

- Repurchase: a defective loan may be repurchased by the seller/servicer from the Enterprises.
- Third-party sale (TPS): a third-party buyer purchases the foreclosure property, instead of the lender.
- Short sale: the owner sells the property directly with sales proceeds short of the debt.
- Real-estate owned (REO): foreclosure properties are most likely purchased by the lender.
- Modified: a loan's term (amortization term, rate, capitalization of the delinquent interest payment, ...) can be modified to cure the loan.
- D180: loans are 180 days delinquent, which is important to model for the fixed severity deals.

Exhibit 6: The overall default performance of U.S. mortgages, grouped by different types of credit events

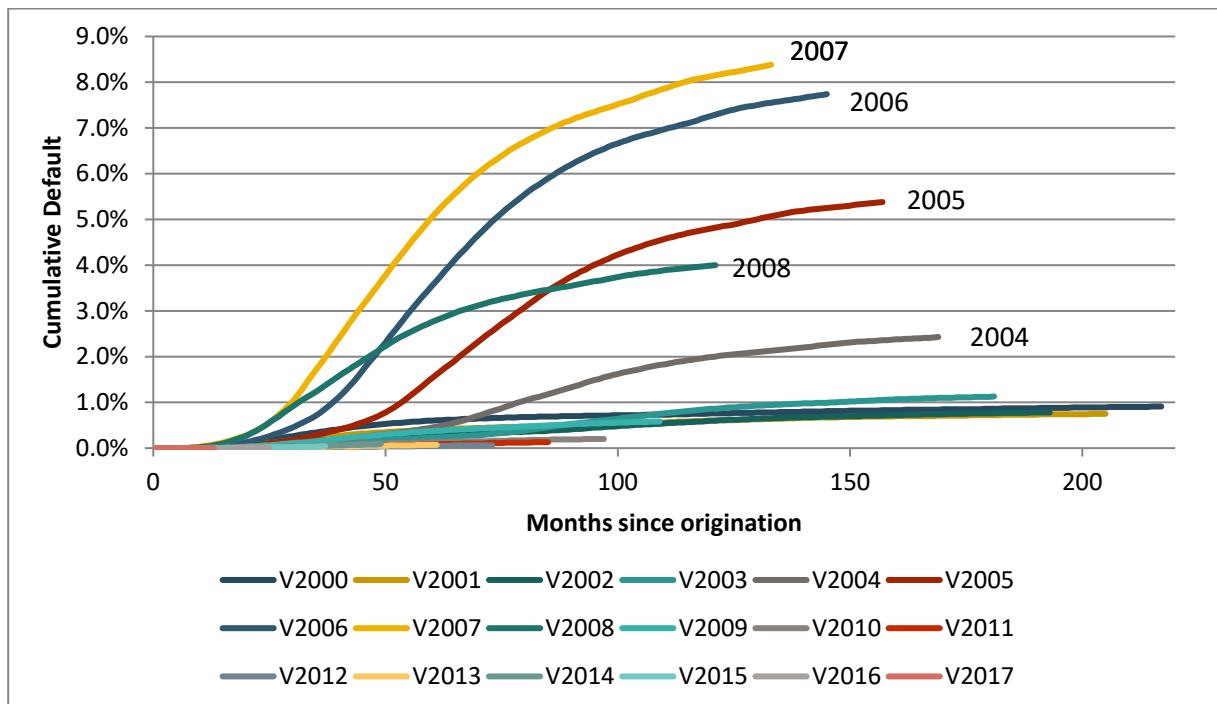


Source: MSCI, Fannie Mae

Exhibit 6 above shows the overall default performance of U.S. mortgages based on Fannie Mae’s loan-level credit performance data across different vintage years. Loans originated during housing boom years (2004 – 2008) experienced the most severe credit events. “D180” has the highest values, as the definition of the “default” in this case is as soon as the loan reaches 180 days past due, which may cure without going into final foreclosure. “Modified” is often the most economically effective way for the seller/servicer to mitigate the loss, especially various government-streamlined programs to assist borrowers, such as Home Affordable Modification Program (HAMP). “REO” is the most probable foreclosure result, with the seller/servicer ending up owning the property. “Repurchase” is a significant loss recovery avenue for the Enterprises, as the seller/servicer had to buy back the defective loans.

Exhibit 7 below delivers a message similar to Exhibit 6, but from the perspective of cumulative default. Loans originated during 2004-2008 show the highest default probability, led by the 2007 vintage. Loans originated after the financial crisis experienced very minimal credit loss, thanks to strong housing price and economy recovery, as well as a much tighter underwriting standard.

Exhibit 7: Cumulative default for Fannie Mae mortgages originated from 2000 to 2017

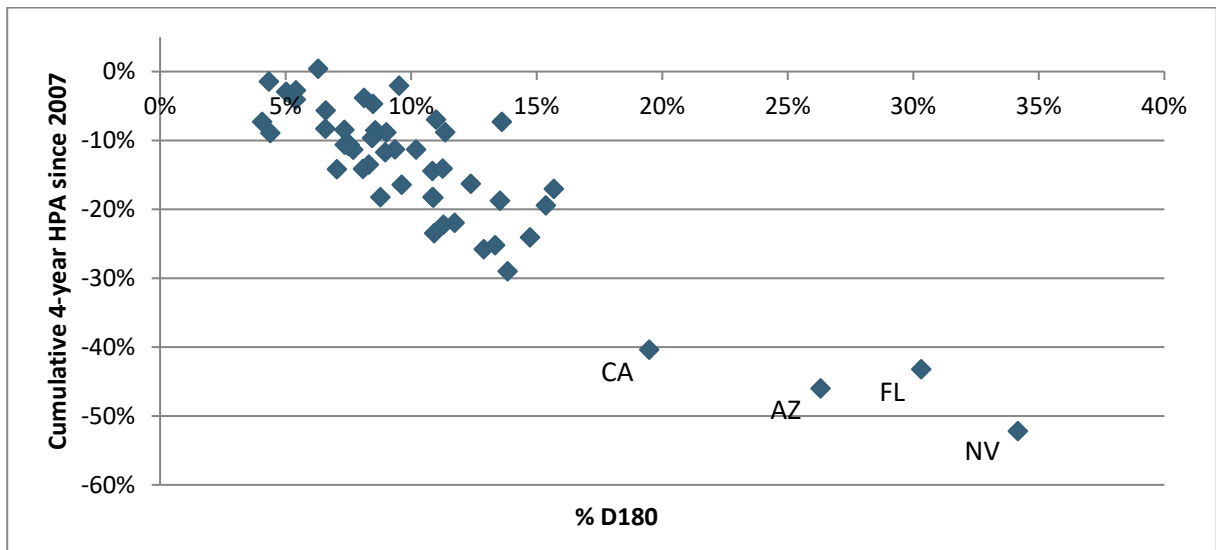


Source: MSCI, Fannie Mae

Housing Price Appreciation (HPA)

Housing price apparently is a major driver of mortgage credit performance. Exhibit 8 below shows the cumulative D180 vs. four-year cumulative HPA across different states. The worst (in terms of HPA) states, such as NV, FL, AZ, and CA, witnessed the highest default rate.

Exhibit 8: Greater housing price drop led to more severe default rate



Source: MSCI, Fannie Mae, FHFA



FICO

FICO is a strong indicator of borrowers' credit performance, especially during the economic downturn and housing price depreciation. Exhibit 9 below demonstrates the cumulative loan default across different FICO buckets and across different origination years. Loans with lower FICO could experience a 3 times higher default probability.

Exhibit 9: Cumulative default by FICO buckets

FICO	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
[0-620]	2.91%	2.80%	2.35%	2.43%	2.94%	4.90%	9.54%	13.75%	15.10%	10.53%	3.81%	3.39%	3.47%	0.17%	0.25%	0.60%	0.21%	0.00%		
[620-640]	2.23%	2.50%	2.08%	2.13%	2.81%	5.03%	10.26%	14.01%	15.37%	10.55%	2.98%	1.43%	0.91%	0.64%	0.38%	0.30%	0.11%	0.05%	0.02%	0.00%
[640-660]	1.93%	1.93%	1.71%	1.76%	2.55%	4.58%	10.02%	13.48%	14.18%	9.78%	2.42%	1.15%	0.71%	0.43%	0.29%	0.27%	0.14%	0.06%	0.01%	0.00%
[660-680]	1.44%	1.33%	1.25%	1.37%	2.11%	4.08%	8.80%	11.91%	12.53%	8.24%	1.78%	0.83%	0.55%	0.32%	0.27%	0.23%	0.12%	0.04%	0.00%	0.00%
[680-700]	0.82%	0.90%	0.87%	1.02%	1.61%	3.22%	7.19%	9.93%	10.61%	6.94%	1.46%	0.61%	0.43%	0.20%	0.20%	0.16%	0.09%	0.03%	0.00%	0.00%
[700-720]	0.67%	0.62%	0.61%	0.76%	1.20%	2.48%	5.76%	8.33%	9.07%	5.55%	1.10%	0.44%	0.27%	0.13%	0.13%	0.11%	0.05%	0.02%	0.00%	0.00%
[720-740]	0.39%	0.39%	0.43%	0.52%	0.90%	1.87%	4.75%	7.02%	7.78%	4.45%	0.87%	0.32%	0.19%	0.11%	0.09%	0.09%	0.04%	0.01%	0.00%	0.00%
[740-760]	0.28%	0.24%	0.24%	0.35%	0.61%	1.38%	3.64%	5.63%	6.15%	3.21%	0.66%	0.23%	0.14%	0.07%	0.06%	0.05%	0.03%	0.01%	0.00%	0.00%
[760-780]	0.14%	0.15%	0.16%	0.21%	0.36%	0.87%	2.68%	3.88%	4.35%	2.13%	0.40%	0.13%	0.07%	0.03%	0.03%	0.04%	0.02%	0.01%	0.00%	0.00%
[780-800]	0.18%	0.14%	0.12%	0.13%	0.24%	0.64%	1.68%	2.62%	2.91%	1.32%	0.24%	0.08%	0.04%	0.02%	0.03%	0.02%	0.01%	0.00%	0.00%	0.00%
[800+]	0.21%	0.15%	0.14%	0.16%	0.25%	0.72%	1.40%	2.07%	2.24%	1.07%	0.20%	0.06%	0.04%	0.02%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%

Source: MSCI, Fannie Mae

Loan-to-Value (LTV)

LTV is a strong indicator of mortgage credit performance, as illustrated in Exhibit 10. Higher original LTV indicates a higher tendency of leverage, which leads to a higher default rate.

Exhibit 10: Cumulative default by original Loan-to-value (LTV) buckets

OLTV	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
[0-60]	0.18%	0.17%	0.10%	0.12%	0.21%	0.55%	1.40%	2.34%	2.15%	0.90%	0.14%	0.03%	0.03%	0.01%	0.01%	0.02%	0.01%	0.00%	0.00%	0.00%
[60-65]	0.37%	0.37%	0.23%	0.31%	0.53%	1.41%	3.90%	5.83%	5.28%	2.22%	0.31%	0.10%	0.06%	0.03%	0.02%	0.03%	0.02%	0.00%	0.00%	0.00%
[65-70]	0.46%	0.54%	0.41%	0.49%	0.85%	2.08%	5.54%	8.04%	7.34%	3.54%	0.53%	0.19%	0.10%	0.04%	0.04%	0.04%	0.01%	0.00%	0.00%	0.00%
[70-75]	0.80%	0.74%	0.55%	0.67%	1.11%	2.52%	6.08%	9.15%	9.20%	3.87%	0.70%	0.24%	0.13%	0.05%	0.04%	0.04%	0.01%	0.01%	0.00%	0.00%
[75-80]	0.60%	0.57%	0.65%	0.82%	1.50%	2.90%	6.47%	8.88%	8.54%	3.85%	0.83%	0.28%	0.17%	0.08%	0.06%	0.05%	0.03%	0.01%	0.00%	0.00%
[80-85]	1.63%	1.52%	1.52%	1.77%	2.57%	4.50%	8.75%	12.27%	14.86%	8.25%	1.39%	0.54%	0.35%	0.15%	0.14%	0.11%	0.05%	0.02%	0.00%	0.00%
[85-90]	1.40%	1.30%	1.65%	2.10%	3.00%	5.31%	9.99%	13.26%	15.98%	8.44%	1.56%	0.45%	0.24%	0.14%	0.10%	0.10%	0.06%	0.02%	0.00%	0.00%
[90-97]	1.69%	1.76%	2.13%	2.69%	4.13%	6.37%	11.59%	14.87%	16.57%	9.41%	2.22%	0.89%	0.41%	0.22%	0.25%	0.23%	0.12%	0.04%	0.01%	0.00%

Source: MSCI, Fannie Mae



Occupancy

As shown in Exhibit 11, investor loans tend to perform much worse than owner-occupied and second homes during a housing crisis. Investors may act rationally as their investment goes underwater, while actual home owners may have an extra attachment to their underwater home that deters their default decision. The relative performance reverses as the housing market recovers.

Exhibit 11: Cumulative default by Occupancy

Occupancy	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Investor	0.69%	1.40%	1.62%	1.80%	1.75%	3.67%	7.07%	10.06%	12.72%	8.04%	0.96%	0.24%	0.11%	0.04%	0.03%	0.02%	0.01%	0.00%	0.00%	0.00%
Owner Occupied	0.91%	0.86%	0.71%	0.73%	1.11%	2.37%	5.29%	7.58%	8.09%	3.72%	0.57%	0.20%	0.13%	0.06%	0.07%	0.09%	0.04%	0.01%	0.00%	0.00%
Second Home	0.41%	0.25%	0.34%	0.46%	0.82%	2.14%	5.23%	7.50%	7.14%	3.70%	0.50%	0.12%	0.10%	0.05%	0.03%	0.04%	0.02%	0.01%	0.00%	0.00%

Source: MSCI, Fannie Mae

Loan Purpose

As shown in Exhibit 12, purchase loans usually perform better than refinance loans. Refinance loans may have appraisal bias and inflated LTV during the housing boom years. Given the same vintage, new home buyers tend to have better income prospects in the near future, compared to mortgage refinancers.

Exhibit 12: Cumulative default by loan purpose

Purpose	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cash-out Refi	1.12%	1.16%	0.68%	0.71%	1.06%	2.55%	5.86%	8.91%	9.20%	4.55%	0.70%	0.30%	0.19%	0.09%	0.07%	0.09%	0.03%	0.01%	0.00%	0.00%
Purchase	0.72%	0.70%	0.83%	1.05%	1.78%	2.68%	5.25%	6.46%	6.27%	3.56%	0.53%	0.18%	0.13%	0.08%	0.09%	0.09%	0.05%	0.02%	0.00%	0.00%
Rate/Term Refi	1.28%	1.44%	0.71%	0.66%	0.91%	1.95%	4.42%	7.75%	10.49%	3.99%	0.53%	0.15%	0.10%	0.04%	0.05%	0.06%	0.03%	0.01%	0.00%	0.00%

Source: MSCI, Fannie Mae



States

Exhibit 13: Cumulative default by non-judicial states

non-judicial	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
AK	1.5%	0.5%	0.4%	0.2%	0.3%	0.9%	1.1%	1.9%	2.9%	1.5%	0.5%	0.2%	0.3%	0.2%	0.2%	0.2%	0.1%	0.0%	0.0%
AL	1.8%	1.7%	1.4%	1.5%	1.5%	2.3%	3.5%	4.7%	6.4%	4.4%	1.3%	0.6%	0.5%	0.3%	0.3%	0.2%	0.1%	0.1%	0.0%
AR	0.9%	1.0%	0.8%	0.8%	1.0%	1.6%	3.0%	4.7%	5.3%	2.8%	0.8%	0.5%	0.4%	0.3%	0.3%	0.3%	0.1%	0.0%	0.0%
AZ	0.9%	0.8%	0.6%	0.6%	1.1%	2.4%	12.5%	21.3%	22.5%	10.3%	1.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
CA	0.2%	0.2%	0.1%	0.1%	0.5%	1.9%	7.1%	11.1%	11.9%	3.3%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CO	0.7%	0.7%	1.0%	1.1%	1.5%	1.8%	2.6%	2.9%	4.2%	2.2%	0.6%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
DC	1.5%	1.5%	0.4%	0.2%	0.2%	0.4%	1.2%	2.6%	3.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
GA	1.5%	1.8%	2.0%	2.7%	3.1%	4.8%	5.7%	7.5%	10.1%	6.6%	1.1%	0.4%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
HI	0.4%	0.2%	0.1%	0.1%	0.1%	0.5%	1.6%	3.1%	4.2%	3.2%	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ID	1.6%	1.6%	1.2%	0.9%	0.9%	1.7%	4.2%	9.2%	10.7%	7.2%	1.6%	0.3%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
MI	1.6%	1.3%	1.7%	2.3%	4.3%	7.1%	10.0%	10.7%	9.9%	4.9%	0.7%	0.2%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
MN	0.5%	0.5%	0.6%	1.0%	2.0%	4.0%	6.5%	7.4%	8.2%	3.9%	0.7%	0.3%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
MO	1.0%	1.0%	0.8%	0.9%	1.3%	2.7%	3.8%	4.9%	6.0%	3.5%	0.8%	0.4%	0.3%	0.1%	0.2%	0.2%	0.1%	0.0%	0.0%
MS	2.2%	1.7%	1.4%	1.4%	1.4%	2.1%	2.5%	4.5%	5.8%	5.0%	1.4%	0.7%	0.5%	0.3%	0.2%	0.2%	0.2%	0.1%	0.0%
MT	1.6%	0.7%	0.3%	0.4%	0.4%	0.8%	1.5%	2.7%	4.9%	3.3%	1.0%	0.4%	0.2%	0.1%	0.1%	0.2%	0.1%	0.0%	0.0%
NC	1.8%	1.7%	1.8%	1.5%	1.4%	1.9%	2.6%	3.9%	5.0%	3.3%	0.8%	0.4%	0.3%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
NE	0.9%	1.0%	0.8%	0.7%	0.9%	1.8%	1.9%	2.3%	2.7%	1.4%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
NH	0.2%	0.2%	0.2%	0.3%	0.9%	2.8%	5.1%	6.0%	6.7%	3.9%	0.7%	0.2%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
NV	0.9%	0.9%	0.6%	0.7%	1.7%	7.2%	19.2%	25.0%	28.0%	13.1%	1.3%	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%
OR	1.6%	1.0%	0.7%	0.5%	0.6%	1.1%	3.1%	6.2%	8.8%	5.0%	0.9%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RI	0.3%	0.1%	0.1%	0.2%	0.8%	2.8%	6.7%	8.3%	8.7%	4.1%	0.6%	0.3%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
TN	1.0%	1.5%	1.4%	1.3%	1.4%	2.0%	2.8%	4.1%	5.3%	3.6%	0.9%	0.4%	0.3%	0.2%	0.2%	0.2%	0.1%	0.0%	0.0%
TX	1.1%	1.3%	1.4%	1.3%	1.1%	1.5%	1.6%	2.5%	3.1%	2.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
UT	3.5%	2.3%	1.5%	0.8%	0.7%	0.8%	1.6%	3.6%	7.1%	4.7%	0.7%	0.2%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%
VA	0.2%	0.3%	0.2%	0.2%	0.3%	1.1%	3.2%	4.9%	5.6%	2.5%	0.4%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
WA	1.1%	0.9%	0.5%	0.4%	0.4%	0.9%	2.2%	4.9%	7.7%	5.3%	1.0%	0.3%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
WV	1.2%	2.1%	1.7%	1.0%	1.2%	2.1%	4.2%	6.5%	6.4%	2.7%	0.9%	0.4%	0.3%	0.2%	0.2%	0.3%	0.1%	0.0%	0.0%
WY	1.2%	0.9%	0.3%	0.3%	0.4%	0.8%	0.8%	1.4%	3.4%	3.1%	0.9%	0.4%	0.3%	0.2%	0.3%	0.4%	0.2%	0.1%	0.0%

Source: MSCI, Fannie Mae

Exhibit 14: Cumulative default by judicial states

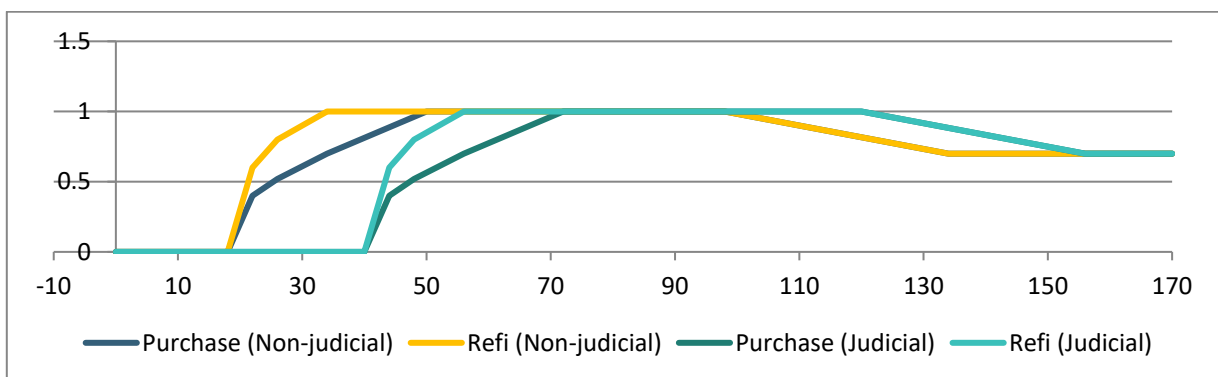
Judicial	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CT	0.4%	0.2%	0.3%	0.3%	0.7%	1.7%	3.7%	5.4%	6.3%	3.5%	0.7%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
DE	0.3%	0.6%	0.5%	0.4%	0.6%	1.3%	3.0%	4.2%	5.6%	3.5%	0.7%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
FL	0.7%	0.6%	0.6%	0.9%	1.7%	4.4%	12.4%	19.4%	19.1%	9.5%	0.9%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
IA	1.4%	1.2%	0.9%	0.9%	1.1%	2.2%	2.8%	3.0%	3.2%	1.4%	0.4%	0.2%	0.2%	0.1%	0.2%	0.1%	0.0%	0.0%	0.0%
IL	0.7%	0.6%	0.5%	0.6%	1.3%	2.8%	5.0%	6.6%	8.4%	5.3%	1.0%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
IN	2.2%	1.9%	2.1%	2.1%	2.5%	3.7%	4.2%	5.1%	5.3%	2.8%	0.6%	0.3%	0.2%	0.1%	0.2%	0.1%	0.0%	0.0%	0.0%
KS	1.3%	1.3%	1.1%	1.1%	1.3%	2.2%	3.2%	3.6%	4.4%	2.4%	0.5%	0.3%	0.2%	0.1%	0.2%	0.1%	0.1%	0.0%	0.0%
KY	2.1%	1.7%	1.7%	1.6%	1.8%	2.9%	3.6%	4.1%	5.0%	2.3%	0.7%	0.4%	0.3%	0.2%	0.2%	0.1%	0.1%	0.0%	0.0%
LA	1.3%	1.4%	1.0%	0.9%	0.9%	1.4%	1.8%	3.4%	4.5%	2.9%	0.6%	0.3%	0.3%	0.2%	0.2%	0.2%	0.1%	0.1%	0.0%
MA	0.0%	0.1%	0.1%	0.2%	0.6%	1.8%	3.8%	4.5%	4.2%	1.7%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MD	0.6%	0.6%	0.2%	0.2%	0.3%	1.0%	3.0%	5.5%	6.9%	3.4%	0.5%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
ME	0.3%	0.1%	0.3%	0.4%	0.8%	2.0%	3.9%	5.2%	6.0%	3.8%	0.9%	0.3%	0.3%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%
ND	0.0%	0.6%	0.4%	0.4%	0.3%	0.7%	0.9%	1.0%	1.1%	0.5%	0.1%	0.1%	0.0%	0.0%	0.1%	0.2%	0.1%	0.0%	0.0%
NJ	0.3%	0.3%	0.2%	0.4%	0.8%	1.9%	4.4%	6.4%	7.5%	4.1%	0.7%	0.3%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
NM	1.5%	1.6%	1.1%	0.6%	0.6%	1.1%	1.9%	4.1%	6.7%	3.7%	1.0%	0.5%	0.3%	0.1%	0.1%	0.2%	0.0%	0.0%	0.0%
NY	0.4%	0.4%	0.3%	0.4%	0.7%	1.5%	2.8%	3.7%	4.2%	2.7%	0.5%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
OH	2.0%	2.0%	2.1%	2.2%	2.7%	4.2%	5.1%	5.3%	5.2%	2.8%	0.6%	0.3%	0.2%	0.2%	0.2%	0.2%	0.1%	0.0%	0.0%
OK	1.9%	1.7%	1.5%	1.5%	1.4%	2.0%	2.8%	2.9%	3.7%	2.9%	0.7%	0.4%	0.3%	0.2%	0.2%	0.3%	0.1%	0.0%	0.0%
PA	1.1%	1.0%	0.7%	0.7%	0.8%	1.7%	2.7%	4.3%	4.5%	3.0%	0.5%	0.3%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
SC	1.7%	2.2%	2.0%	2.2%	1.8%	2.2%	3.4%	5.7%	6.1%	4.2%	1.0%	0.3%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
SD	1.9%	0.8%	0.5%	0.8%	0.6%	1.6%	1.5%	1.9%	2.5%	1.3%	0.4%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
VT	0.3%	0.4%	0.2%	0.2%	0.3%	1.1%	1.8%	3.3%	3.3%	2.0%	0.6%	0.2%	0.2%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%
WI	0.4%	0.6%	0.5%	0.4%	0.9%	2.2%	4.0%	4.2%	5.1%	2.5%	0.5%	0.3%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
PR	0.3%	0.9%	0.6%	0.9%	1.0%	1.6%	2.1%	3.5%	2.7%	2.5%	1.8%	0.7%	0.7%	0.5%	0.2%	0.1%	0.0%	0.0%	0.0%

Source: MSCI, Fannie Mae

Exhibit 13 and 14 illustrate the cumulative default for non-judicial and judicial states, respectively. States that experienced a more severe housing downturn show high default rates. Judicial states show a much longer default time line for disposition due to their more vigorous foreclosure procedure, as shown in Exhibit 15. We do not differentiate between judicial and non-judicial regarding an 180D credit event, as shown in Exhibit 16. Purchase loans show a slower age ramp compared to refinance loans.

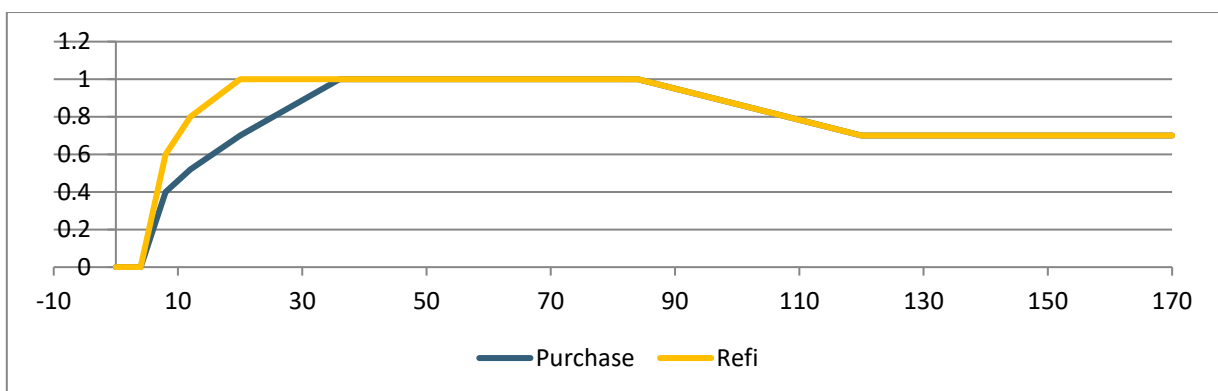
Age Ramp

Exhibit 15: Age ramp for disposition default



Source: MSCI, Fannie Mae

Exhibit 16: Age ramp for 180D

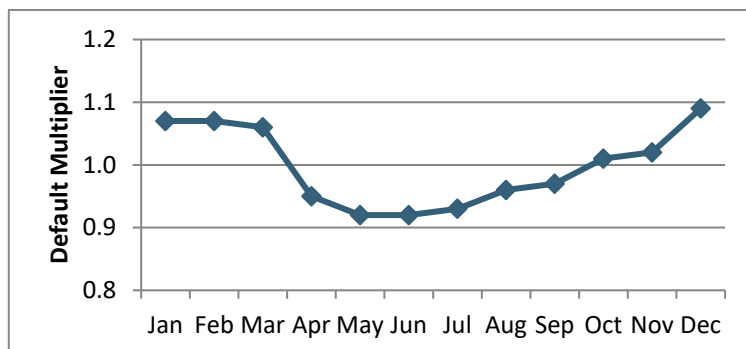


Source: MSCI, Fannie Mae

Seasonality

As shown in Exhibit 17 below, loan default behavior exhibits mild seasonality. Default is usually lower in the summer, starting from the tax refund month. Winter usually sees higher overdue payments.

Exhibit 17: Seasonality

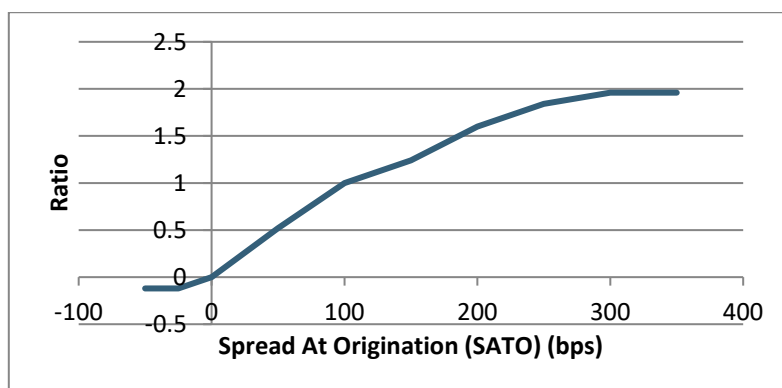


Source: MSCI, Fannie Mae

Spread-at-Origination (SATO)

The SATO curve models the residual effect of the loan's credit performance after the explicit credit variables (FICO and LTV). Higher SATO represents weaker credit, possibly not yet reflected in the credit score. Borrowers with an imperfect credit profile may get loans with higher rates to partially offset their credit risk. Exhibit 18 illustrate the SATO effect.

Exhibit 18: Spread-at-origination (SATO)

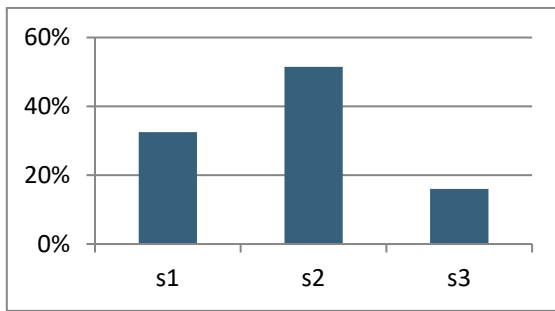


Source: MSCI

Credit Burnout

As the bond ages and refinance opportunities arise, borrowers with better credit profiles will take advantage of the more favorable mortgage terms by refinancing. The remaining mortgages tend to face higher hurdles in terms of credit access, and they are more vulnerable to an adverse economic downturn. We adopt a dynamic population burnout approach to deal with the credit burnout issue. Exhibit 19 shows the scheme of distribution of borrowers as high (S1), medium (S2), and low (S3). As the subpopulations with higher voluntary prepayment propensities leave the pool, the proportion of the lower credit subpopulations will naturally increase.

Exhibit 19: Population-based credit burnout approach

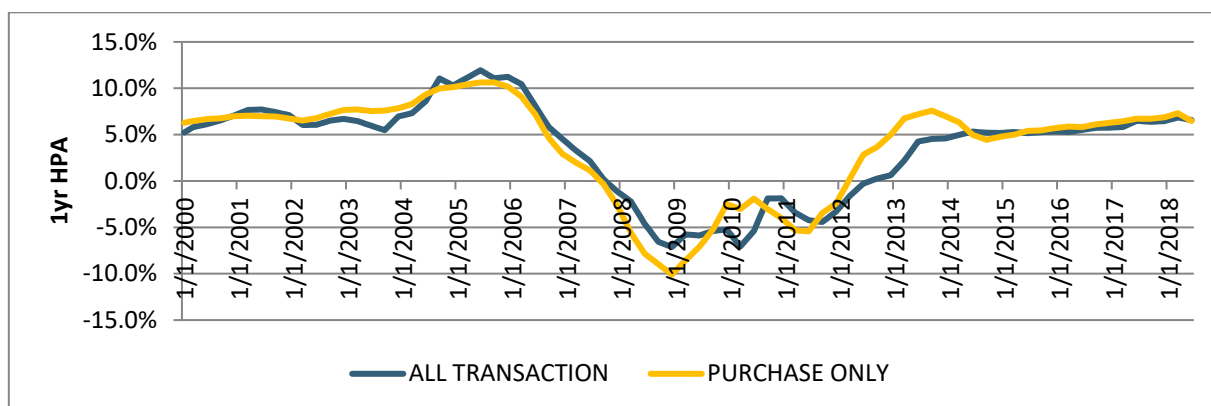


Source: MSCI

Different HPI Indexes

The reported housing prices for refinanced loans are appraised values via either AVM or an actual appraisal. Therefore, the housing price indexes based on All Transaction could be significantly different from Purchase Only indexes, as shown in Exhibit 20. When we mark-to-market for the CLTV calculation, we incorporate this appraisal bias. We use both All-Transaction and Purchase-Only state-level housing price indexes from FHFA. This is especially important when the HPA momentum started its turning point, as in 2007. The lagging All Transaction index could significantly underestimate the HPA change. In reality, what matters to the borrowers' default behavior is the Purchase Only index, i.e., at what market price the home owner can sell their houses to avoid default and mitigate the financial hardship, not the appraisal prices. Note: As FHFA HPI indexes (and other major HPI indexes) are based on a repeated-sales methodology, the historical values of the index may change significantly. During the period of financial crisis then, the difference between the two indexes was even bigger.

Exhibit 20: Housing price index: all-transaction vs. purchase-only



Source: MSCI, FHFA

Hidden Debt

During the years of the housing boom, borrowers took second-lien mortgages, either to avoid mortgage insurance or to tap into home equity. This additional hidden debt reduces the refinance intensity of the loans with otherwise seemingly "lower" LTV. Meanwhile, this subsequent debt is an additional burden on these borrowers, increasing their default probability.

5 Loss Severity Model

Two factors affect the final loss of the mortgage credit risk: probability of default, and loss severity. Since 2014, the Enterprises started to release loan-level credit performance data beyond 180D delinquency and actual loss severity data to support the CRT deal structure evolving from a fixed-severity schedule to actual loss. We utilize this rich dataset to build our loss severity model.

The MSCI loss severity model deploys a financial accounting approach, decomposing the financials into individual components:

$$\text{Loss Severity} = \$100 + \text{Interest} + \text{Expense} - \text{Sales} - \text{MI recovery} - \text{non-MI recovery}$$

where:

- “Interest” represents delinquent interest cost.
- “Expense” includes foreclosure cost, property preservation cost, asset recovery cost, tax cost, and other miscellaneous costs.
- “Sales” represents net sales proceeds.
- “MI recovery” represents credit enhancement proceeds due to mortgage insurance (MI) payments.
- “non-MI recovery” includes loan repurchase and make-whole payments.

Exhibit 21: Summary of the main loss severity model drivers

Factor\Components	Interest	Expense	Sales Proceeds	MI Recovery	Non-MI Recovery
States	+	+			
WAC	+				
LTV			+		
Loan size (original)		+	+		
Loan size (current)		+			
Occupancy/Purpose			+		
MI				+	
SATO					+

Source: MSCI



Exhibit 22 below shows the overall individual loss components. The universe is divided into below and above 80 LTV. Loans with LTV greater than 80 are usually required to have mortgage insurance (MI), which subsequently leads to higher MI recovery and lower overall loss severity. In general, loans originated before the financial crisis carry higher interest rates, therefore higher lost interest. The net sales proceeds are usually lower for loans originated during years with peak housing prices.

Exhibit 22: Loss components and loss severity, LTV<=80 vs. 80<LTV<=97

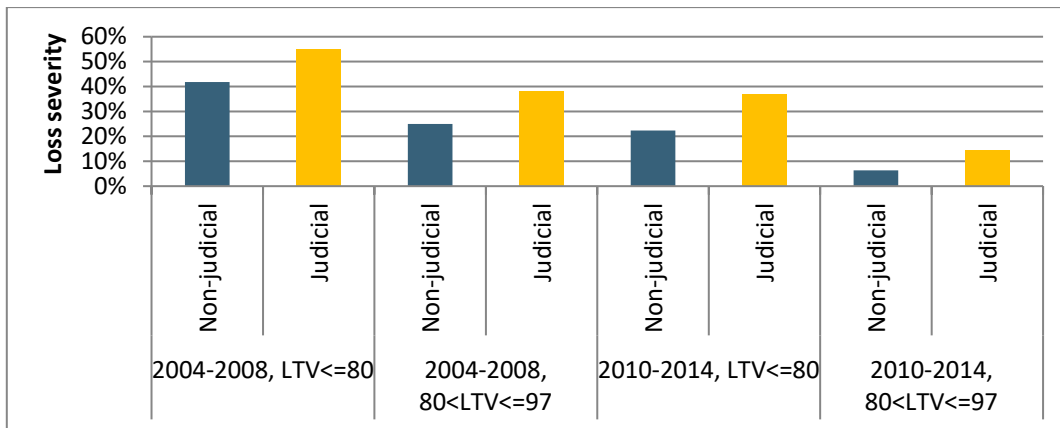
Cohort	LTV<=80							80<LTV<=97						
	Default UPB (\$M)	Interest	Expense	Proceeds	MI recovery	Non-MI recovery	Severity	Default UPB (\$M)	Interest	Expense	Proceeds	MI recovery	Non-MI recovery	Severity
1999	67	12.8%	12.3%	85.5%	0.6%	16.2%	22.9%	102	11.5%	10.9%	80.0%	23.0%	7.9%	11.5%
2000	545	13.4%	13.2%	78.0%	0.5%	18.7%	29.4%	840	12.2%	11.4%	77.3%	24.1%	9.2%	13.0%
2001	1,634	11.9%	14.0%	77.1%	0.1%	13.0%	35.8%	1,860	10.9%	11.7%	74.5%	22.7%	7.4%	18.0%
2002	2,373	12.0%	15.5%	78.8%	0.0%	9.5%	39.2%	2,004	11.1%	13.0%	71.5%	22.0%	6.6%	24.0%
2003	5,722	11.1%	15.1%	84.6%	0.0%	5.2%	36.5%	3,037	10.6%	13.8%	72.0%	20.4%	4.3%	27.6%
2004	4,569	11.3%	13.7%	79.3%	0.0%	3.8%	41.9%	2,061	11.4%	13.7%	67.3%	21.6%	4.2%	32.0%
2005	10,428	10.7%	10.5%	71.2%	0.0%	3.4%	46.6%	3,090	11.4%	11.6%	61.0%	22.6%	4.7%	34.7%
2006	11,978	11.6%	9.7%	65.1%	0.0%	5.2%	51.0%	3,325	12.0%	10.4%	56.5%	23.5%	6.7%	35.7%
2007	13,501	11.7%	9.7%	65.1%	0.0%	7.6%	48.7%	6,955	11.7%	9.7%	56.8%	23.2%	9.5%	31.9%
2008	7,383	11.7%	10.5%	69.1%	0.0%	10.6%	42.5%	5,209	10.6%	8.9%	62.0%	21.9%	11.5%	24.1%
2009	2,392	9.4%	10.9%	80.1%	0.0%	7.0%	33.2%	637	7.5%	8.6%	73.8%	19.0%	5.5%	17.9%
2010	671	8.6%	13.1%	85.0%	0.0%	5.0%	31.7%	191	6.9%	9.9%	79.7%	20.6%	3.3%	13.2%
2011	320	7.8%	14.0%	86.3%	0.0%	4.0%	31.6%	139	7.2%	11.5%	83.5%	21.2%	2.2%	11.7%
2012	222	6.3%	13.4%	88.8%	0.0%	2.9%	27.9%	153	5.9%	12.3%	83.6%	21.5%	2.6%	10.5%
2013	142	6.0%	13.1%	90.6%	0.0%	4.0%	24.6%	194	6.0%	11.5%	80.5%	25.2%	3.2%	8.7%
2014	87	6.1%	11.6%	92.1%	0.0%	5.1%	20.5%	161	6.1%	10.0%	81.0%	25.3%	2.8%	7.0%
2015	51	5.2%	9.8%	92.9%	0.0%	3.6%	18.5%	106	5.0%	8.7%	83.5%	21.7%	3.3%	5.2%
2016	22	4.2%	7.3%	91.8%	0.0%	4.3%	15.5%	46	4.1%	7.1%	84.9%	18.0%	2.6%	5.7%
2017	5	3.4%	5.1%	86.3%	0.0%	9.6%	12.6%	9	3.4%	4.8%	77.5%	19.2%	7.2%	4.4%

Source: Fannie Mae, MSCI

States

Exhibit 23 shows the overall loss severity, comparing judicial and non-judicial states. The origination years are divided into before and after the financial crisis. LTV is grouped as below and above 80. The judicial states' loss severity is much higher than for the non-judicial states, due to the judicial states' longer and more complicated foreclosure legal procedure.

Exhibit 23: Judicial and non-judicial states, overall severity



Source: MSCI, Fannie Mae

Exhibit 24 details the loss breakdown for judicial vs. non-judicial states. Default loans in judicial states experience a longer liquidation timeline, causing higher lost interest cost and expense.

Exhibit 24: Judicial and non-judicial states, individual loss components

Cohort	State	Default UPB (\$M)	Interest	Expense	Proceeds	MI recovery	Non-MI recovery	Severity
2004-2008, LTV<=80	Non-judicial	\$28,248	8.7%	7.1%	68.0%	0.0%	6.0%	41.8%
	Judicial	\$19,602	15.3%	15.0%	68.9%	0.0%	6.5%	55.0%
2004-2008, 80<LTV<=97	Non-judicial	\$11,186	8.8%	7.5%	61.2%	22.2%	7.9%	25.0%
	Judicial	\$9,452	14.5%	13.6%	58.0%	23.2%	8.8%	38.1%
2010-2014, LTV<=80	Non-judicial	\$714	6.4%	10.5%	89.2%	0.0%	5.4%	22.3%
	Judicial	\$730	8.9%	16.0%	84.6%	0.0%	3.3%	37.0%
2010-2014, 80<LTV<=97	Non-judicial	\$437	5.6%	9.2%	82.9%	22.3%	3.2%	6.3%
	Judicial	\$404	7.3%	12.9%	80.0%	23.3%	2.5%	14.4%

Source: Fannie Mae, MSCI

LTV

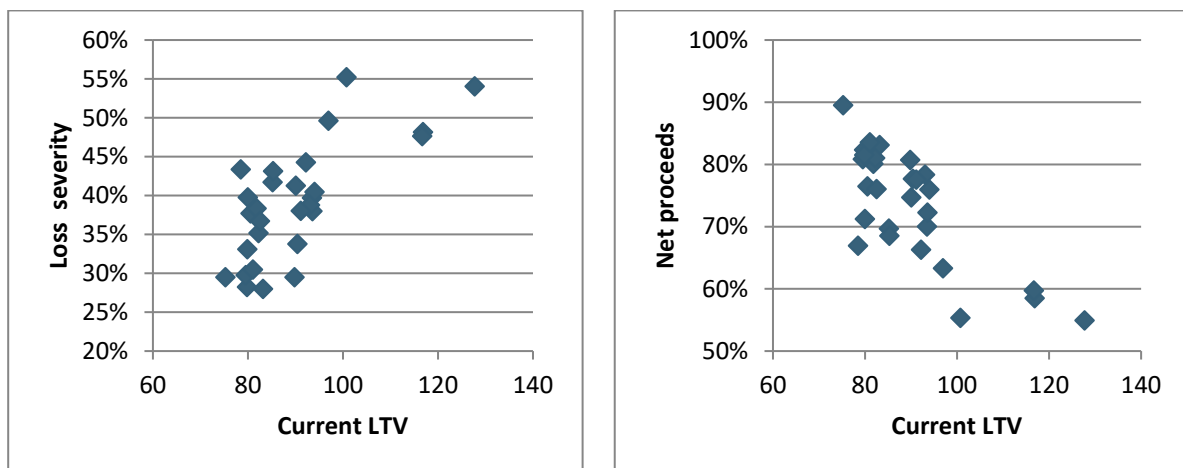
Severity for original LTV>80 loans are lower than loans with original LTV above 80, due to MI recovery, as shown in Exhibit 25. Exhibit 26 and 27 illustrate that higher current LTV leads to lower net sales proceeds. This causes a higher loss severity.

Exhibit 25: Original LTV, individual loss components

LTV	2004-2008							2010-2014						
	Default UPB (\$M)	Interest	Expense	Proceeds	MI recovery	Non-MI recovery	Severity	Default UPB (\$M)	Interest	Expense	Proceeds	MI recovery	Non-MI recovery	Severity
(0-60]	\$4,004	13.1%	14.8%	85.2%	0.0%	5.3%	37.4%	\$115	7.5%	16.3%	99.1%	0.0%	3.8%	21.0%
(60-65]	\$3,029	12.2%	12.0%	74.4%	0.0%	5.1%	44.7%	\$68	8.1%	14.9%	92.2%	0.0%	3.2%	27.5%
(65-70]	\$6,890	11.8%	11.0%	69.5%	0.0%	5.8%	47.6%	\$162	8.1%	14.5%	87.8%	0.0%	4.9%	29.9%
(70-75]	\$7,259	11.6%	10.4%	65.9%	0.0%	6.9%	49.1%	\$288	8.1%	13.5%	84.1%	0.0%	4.3%	33.2%
(75-80]	\$26,677	10.9%	9.4%	65.6%	0.0%	6.4%	48.3%	\$810	7.4%	12.3%	85.5%	0.0%	4.4%	29.9%
(80-85]	\$2,814	11.6%	10.5%	60.3%	10.9%	9.0%	41.9%	\$108	6.7%	12.1%	84.2%	9.5%	2.2%	22.9%
(85-90]	\$9,475	11.7%	10.4%	58.8%	22.1%	8.7%	32.4%	\$215	6.7%	11.4%	82.9%	20.4%	3.3%	11.5%
(90-97]	\$8,351	11.0%	10.1%	60.7%	27.3%	7.5%	25.6%	\$514	6.2%	10.6%	80.3%	26.6%	2.8%	7.0%

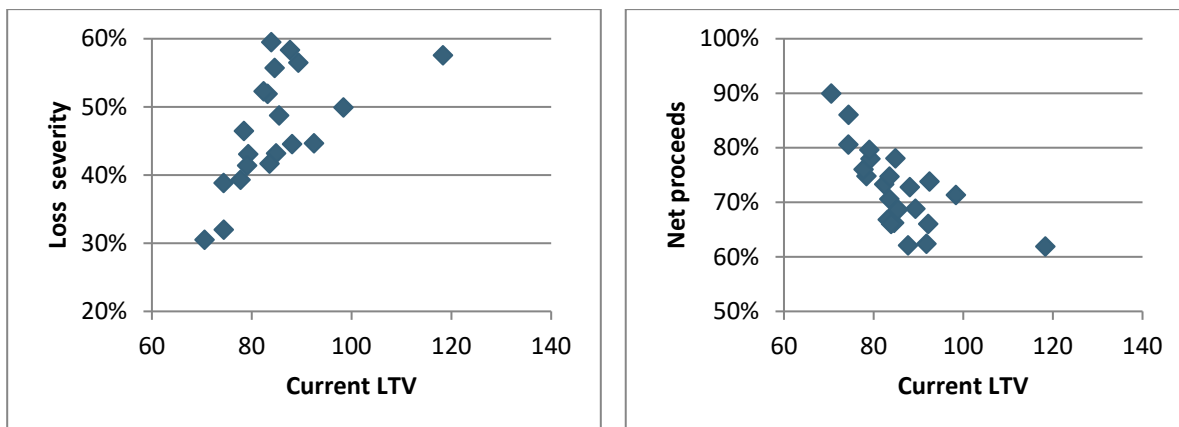
Source: Fannie Mae, MSCI

Exhibit 26: Non-judicial states: high current LTV leads to lower net proceeds and higher loss severity



Source: MSCI

Exhibit27: Judicial states: high current LTV leads to lower net proceeds and higher loss severity

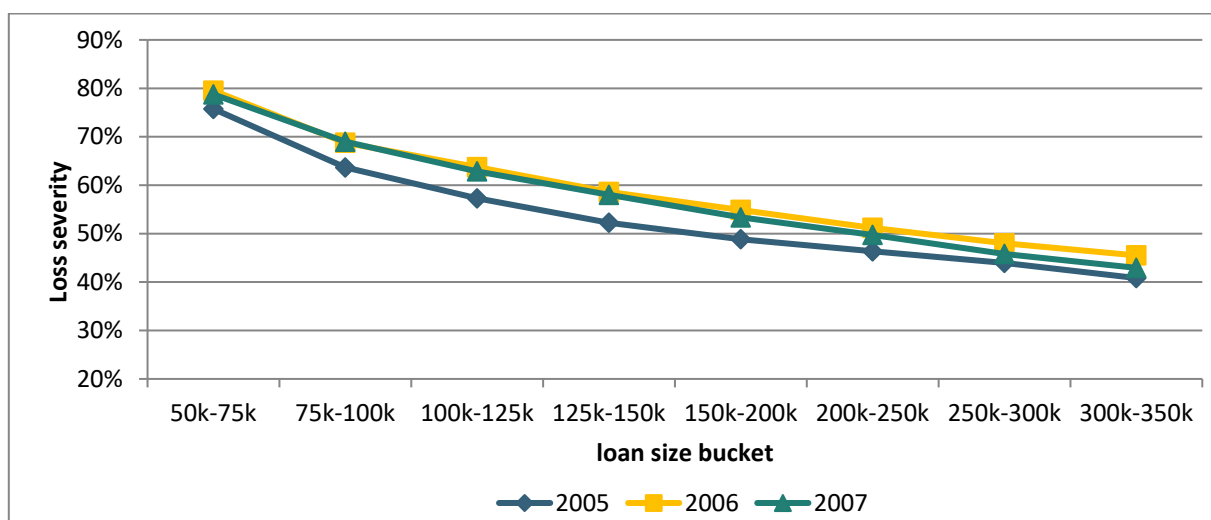


Source: MSCI

Loan Size

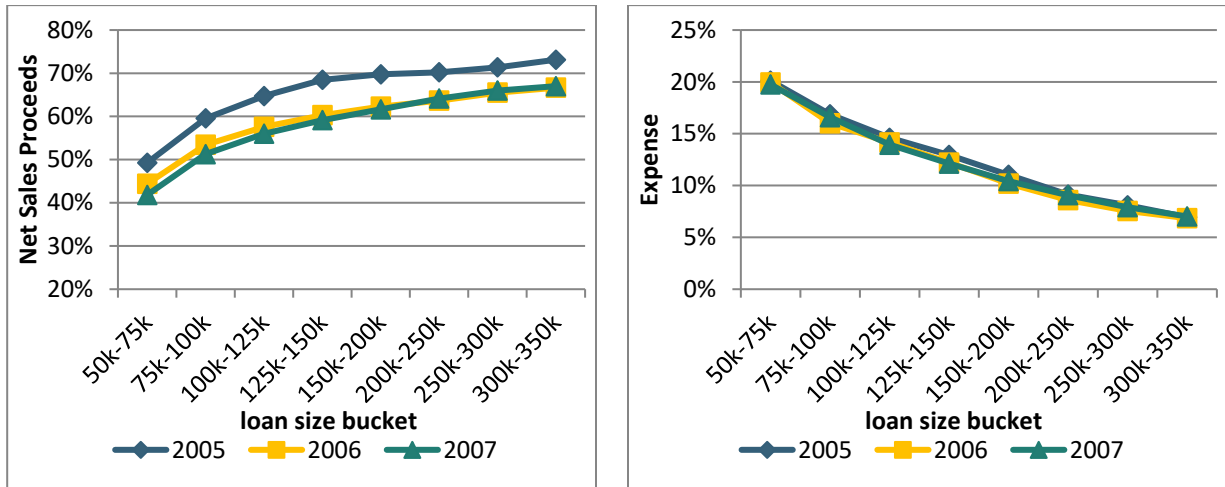
Loans with smaller loan size show higher severity, as shown in Exhibit 28. Exhibit 29 reveals lower net sales proceeds and higher expense due to the fixed costs of legal and financial procedures, which leads to a higher cost percentage of defaulted balance.

Exhibit 28: Loss severity and loan size



Source: Fannie Mae, MSCI

Exhibit 29: loan size and net sales proceeds and expense



Source: MSCI

Purpose

Refinance loans show higher severity, driven by lower net sale proceeds. The inflated housing price for refinance loans due to appraisal bias is the culprit for this phenomenon. Cashout also contributes to worse refinance loans' loss severity.

Exhibit 30: Purpose (purchase vs. refinance) with 60<LTV<=80

Cohort	Default UPB (\$M)		Interest		Expense		Proceeds		MI recovery		Non-MI recovery		Severity	
	purchase	refinance	purchase	refinance	purchase	refinance	purchase	refinance	purchase	refinance	purchase	refinance	purchase	refinance
1999	\$18	\$44	12.2%	12.7%	11.8%	12.3%	92.3%	81.2%	1.1%	0.4%	15.9%	17.2%	14.7%	26.2%
2000	\$166	\$344	12.6%	13.8%	12.8%	12.7%	87.0%	72.6%	0.7%	0.4%	15.8%	19.9%	22.0%	33.5%
2001	\$274	\$1,267	12.1%	11.9%	13.9%	13.6%	88.0%	74.0%	0.1%	0.0%	11.4%	13.0%	26.4%	38.4%
2002	\$389	\$1,809	12.6%	11.8%	15.7%	14.9%	87.6%	75.3%	0.1%	0.0%	7.3%	9.7%	33.3%	41.7%
2003	\$904	\$4,311	11.5%	11.0%	14.5%	14.7%	89.1%	81.8%	0.0%	0.0%	3.8%	5.1%	33.0%	38.8%
2004	\$1,207	\$2,970	11.4%	11.2%	12.8%	13.5%	82.1%	75.8%	0.0%	0.0%	2.8%	4.0%	39.3%	44.9%
2005	\$3,021	\$6,539	10.1%	10.8%	9.3%	10.5%	71.5%	68.7%	0.0%	0.0%	3.0%	3.5%	44.8%	49.1%
2006	\$3,294	\$7,620	10.7%	11.8%	8.4%	9.6%	67.2%	62.0%	0.0%	0.0%	4.8%	5.5%	47.1%	53.8%
2007	\$2,709	\$9,739	10.4%	11.8%	8.4%	9.6%	69.6%	62.1%	0.0%	0.0%	7.1%	7.9%	42.1%	51.4%
2008	\$1,411	\$5,345	12.4%	11.3%	10.0%	10.0%	68.1%	67.3%	0.0%	0.0%	17.5%	9.1%	36.9%	44.9%
2009	\$351	\$1,806	11.0%	8.9%	12.3%	10.2%	77.3%	78.7%	0.1%	0.0%	12.4%	6.1%	33.5%	34.1%
2010	\$132	\$491	9.3%	8.5%	13.5%	12.5%	88.9%	82.6%	0.0%	0.0%	6.2%	4.7%	27.7%	33.6%
2011	\$69	\$223	7.9%	7.9%	13.5%	13.9%	89.8%	83.6%	0.0%	0.0%	3.9%	4.0%	27.7%	34.2%
2012	\$44	\$160	6.4%	6.2%	13.8%	12.9%	92.4%	86.7%	0.0%	0.0%	3.5%	2.7%	24.3%	29.7%
2013	\$36	\$94	6.1%	6.0%	13.7%	12.7%	95.2%	87.6%	0.0%	0.0%	4.7%	3.5%	19.9%	27.6%
2014	\$26	\$54	6.2%	6.2%	12.4%	11.4%	94.4%	90.1%	0.0%	0.0%	8.3%	3.8%	15.9%	23.7%
2015	\$11	\$35	5.2%	5.3%	10.0%	9.9%	98.8%	90.6%	0.0%	0.0%	2.0%	4.6%	14.3%	20.0%
2016	\$5	\$15	3.7%	4.5%	5.9%	8.0%	101.0%	90.6%	0.0%	0.0%	1.3%	2.9%	7.3%	18.9%
2017	\$2	\$3	3.7%	3.2%	4.3%	6.2%	103.7%	73.9%	0.0%	0.0%	0.0%	17.7%	4.3%	17.9%

Source: Fannie Mae, MSCI



Exhibit 31: Purpose (purchase vs. refinance) with 80<LTV<=97

Cohort	Default UPB (\$M)		Interest		Expense		Proceeds		MI recovery		Non-MI recovery		Severity	
	purchase	refinance	purchase	refinance	purchase	refinance	purchase	refinance	purchase	refinance	purchase	refinance	purchase	refinance
1999	\$74	\$29	11.5%	11.3%	11.4%	9.6%	81.3%	76.6%	24.3%	19.8%	6.8%	10.7%	10.6%	13.7%
2000	\$633	\$207	12.1%	12.6%	11.6%	10.6%	79.1%	71.7%	25.0%	21.3%	8.2%	12.4%	11.4%	17.8%
2001	\$929	\$931	10.8%	11.0%	11.9%	11.4%	76.4%	72.5%	24.0%	21.4%	7.5%	7.4%	14.8%	21.2%
2002	\$1,050	\$954	11.3%	10.8%	13.7%	12.2%	72.6%	70.3%	24.0%	19.8%	7.7%	5.4%	20.7%	27.6%
2003	\$1,622	\$1,415	11.1%	10.2%	14.3%	13.1%	72.8%	71.1%	23.1%	17.3%	4.8%	3.8%	24.6%	31.1%
2004	\$1,355	\$706	11.8%	10.7%	13.9%	13.3%	68.1%	65.8%	23.3%	18.2%	4.4%	3.7%	29.9%	36.1%
2005	\$1,955	\$1,135	11.3%	11.4%	11.4%	11.8%	60.9%	61.2%	24.6%	19.1%	4.7%	4.5%	32.5%	38.4%
2006	\$2,004	\$1,321	11.8%	12.3%	10.3%	10.6%	57.4%	55.3%	25.4%	20.7%	6.5%	7.0%	32.9%	39.9%
2007	\$3,211	\$3,744	11.3%	12.0%	9.6%	9.8%	59.3%	54.8%	24.8%	21.9%	10.0%	9.0%	26.9%	36.2%
2008	\$3,028	\$2,181	10.6%	10.6%	8.8%	9.1%	63.3%	60.3%	22.9%	20.5%	13.3%	9.0%	20.0%	29.9%
2009	\$247	\$390	8.2%	7.1%	9.4%	8.2%	76.4%	72.1%	20.2%	18.3%	5.9%	5.2%	15.1%	19.6%
2010	\$87	\$104	7.1%	6.7%	10.1%	9.8%	81.9%	78.0%	21.7%	19.6%	4.0%	2.8%	9.7%	16.1%
2011	\$72	\$66	7.5%	6.9%	11.6%	11.4%	87.3%	79.4%	21.0%	21.4%	3.1%	1.3%	7.7%	16.2%
2012	\$82	\$71	6.0%	5.7%	12.5%	12.1%	84.4%	82.7%	23.1%	19.7%	3.2%	2.0%	8.0%	13.4%
2013	\$141	\$53	6.2%	5.4%	11.6%	11.2%	81.5%	77.9%	26.7%	21.1%	3.5%	2.2%	6.2%	15.4%
2014	\$130	\$32	6.2%	5.8%	10.0%	10.1%	80.9%	81.3%	26.7%	19.3%	3.0%	2.2%	5.6%	13.1%
2015	\$87	\$18	5.1%	4.7%	8.8%	8.5%	82.9%	86.6%	22.8%	16.8%	3.7%	1.5%	4.5%	8.4%
2016	\$39	\$8	4.3%	3.4%	7.3%	5.8%	84.6%	86.4%	19.2%	12.3%	2.9%	0.9%	4.9%	9.5%
2017	\$8	\$1	3.4%	3.2%	5.1%	1.5%	76.8%	89.1%	19.4%	15.2%	7.6%	0.2%	4.7%	0.2%

Source: Fannie Mae, MSCI



Occupancy

Investor loans have much higher loss severity, due to lower net sales proceeds and higher disposition expense. Note: Investor loans originated during the housing boom years did show higher non-MI recovery, as investor loans are probably more likely to be faulty and subject to repurchase.

Exhibit 32: Occupancy (owner occupied, investor and second home) with 60<LTV<=80

Cohort	Default UPB (\$M)			Interest			Expense			Proceeds			MI recovery			Non-MI recovery			Severity		
	Owner	Investor	2nd	Owner	Investor	2nd	Owner	Investor	2nd	Owner	Investor	2nd	Owner	Investor	2nd	Owner	Investor	2nd	Owner	Investor	2nd
1999	\$58	\$3	\$1	12.4%	14.8%	14.0%	12.0%	17.4%	7.6%	85.5%	67.8%	74.9%	0.6%	0.8%	0.0%	15.9%	29.7%	33.5%	22.5%	33.9%	13.2%
2000	\$457	\$48	\$6	13.3%	14.4%	10.8%	12.3%	16.9%	13.5%	79.9%	51.7%	82.2%	0.3%	1.9%	2.3%	17.3%	31.5%	12.8%	28.0%	46.2%	27.0%
2001	\$1,322	\$203	\$16	11.7%	12.9%	12.6%	13.1%	17.2%	14.3%	80.0%	53.1%	85.2%	0.1%	0.1%	0.0%	11.9%	18.4%	9.7%	32.9%	58.6%	31.9%
2002	\$1,857	\$306	\$35	11.9%	12.1%	13.4%	14.7%	16.8%	15.0%	81.8%	50.4%	85.1%	0.0%	0.1%	0.2%	8.3%	15.3%	8.5%	36.5%	63.2%	34.6%
2003	\$4,670	\$448	\$98	11.0%	11.7%	11.5%	14.4%	17.7%	13.5%	85.3%	58.5%	86.3%	0.0%	0.0%	0.0%	4.6%	7.2%	5.7%	35.4%	63.7%	33.0%
2004	\$3,758	\$291	\$128	11.2%	12.3%	11.5%	13.1%	17.1%	12.1%	79.4%	55.0%	78.3%	0.0%	0.0%	0.1%	3.5%	6.0%	3.8%	41.4%	68.4%	41.5%
2005	\$8,662	\$500	\$398	10.6%	11.8%	9.8%	10.1%	12.7%	8.0%	70.7%	54.2%	66.0%	0.0%	0.0%	0.0%	3.1%	7.5%	4.3%	46.9%	62.7%	47.5%
2006	\$9,682	\$743	\$489	11.4%	12.1%	10.7%	9.2%	10.5%	7.4%	64.5%	52.7%	61.1%	0.0%	0.0%	0.0%	4.8%	10.9%	6.1%	51.3%	58.9%	50.9%
2007	\$10,642	\$1,310	\$496	11.4%	12.2%	10.7%	9.3%	10.0%	7.4%	65.1%	53.1%	61.6%	0.0%	0.1%	0.0%	6.8%	14.2%	10.2%	48.8%	54.8%	46.4%
2008	\$5,214	\$1,234	\$308	11.4%	12.3%	10.9%	9.9%	11.0%	7.8%	70.9%	53.3%	65.9%	0.0%	0.1%	0.0%	8.5%	19.8%	14.5%	41.9%	50.2%	38.3%
2009	\$1,929	\$136	\$9	9.1%	10.8%	8.8%	10.4%	13.1%	8.1%	80.2%	58.0%	72.3%	0.0%	0.2%	0.0%	6.2%	18.1%	11.1%	33.1%	47.6%	33.4%
2010	\$559	\$45	\$19	8.5%	10.1%	8.2%	12.5%	16.1%	11.0%	85.2%	68.0%	82.0%	0.0%	0.0%	0.0%	4.6%	9.0%	9.4%	31.2%	49.2%	27.9%
2011	\$256	\$23	\$12	7.8%	9.1%	6.7%	13.6%	17.9%	9.8%	86.4%	71.4%	84.3%	0.0%	0.0%	0.0%	3.6%	7.2%	5.3%	31.5%	48.5%	27.0%
2012	\$183	\$12	\$8	6.2%	6.9%	6.7%	13.0%	16.7%	9.1%	89.4%	75.2%	74.2%	0.0%	0.0%	0.0%	2.9%	3.5%	0.6%	26.9%	44.9%	40.9%
2013	\$118	\$9	\$3	5.9%	6.8%	6.1%	12.7%	17.1%	12.0%	90.1%	83.4%	93.5%	0.0%	0.0%	0.0%	3.9%	3.7%	2.5%	24.7%	36.8%	22.1%
2014	\$73	\$5	\$2	6.1%	7.6%	6.5%	11.4%	16.2%	15.1%	91.6%	90.4%	90.6%	0.0%	0.0%	0.0%	5.5%	3.5%	0.4%	20.3%	29.9%	30.6%
2015	\$43	\$2	\$1	5.2%	5.8%	5.1%	9.8%	12.0%	11.6%	92.8%	82.8%	100.3%	0.0%	0.0%	0.0%	4.2%	2.2%	1.1%	18.1%	32.8%	15.4%
2016	\$19	\$1	\$1	4.3%	4.1%	3.5%	7.4%	8.3%	8.0%	93.3%	86.3%	104.3%	0.0%	0.0%	0.0%	2.7%	0.1%	1.6%	15.7%	25.9%	5.6%
2017	\$4	\$0	-	3.3%	4.5%	-	4.2%	22.6%	-	83.1%	108.7%	-	0.0%	0.0%	-	11.9%	0.5%	-	12.5%	17.9%	-

Source: Fannie Mae, MSCI

Exhibit 33: Occupancy (owner occupied, investor and second home) with 80<LTV<=97

Cohort	Default UPB (\$M)			Interest			Expense			Proceeds			MI recovery			Non-MI recovery			Severity		
	Owner	Investor	2nd	Owner	Investor	2nd	Owner	Investor	2nd	Owner	Investor	2nd	Owner	Investor	2nd	Owner	Investor	2nd	Owner	Investor	2nd
1999	\$100	\$1	\$1	11.5%	9.8%	10.4%	11.0%	11.3%	4.9%	80.0%	65.0%	88.5%	23.1%	22.8%	15.0%	8.0%	4.6%	0.6%	11.3%	28.7%	11.2%
2000	\$803	\$30	\$7	12.2%	12.6%	13.1%	11.3%	12.9%	12.6%	77.8%	62.0%	81.9%	24.1%	25.1%	20.8%	8.8%	20.8%	11.6%	12.8%	17.6%	11.3%
2001	\$1,747	\$92	\$21	10.9%	11.6%	11.7%	11.5%	14.2%	13.6%	75.6%	51.6%	82.5%	22.7%	23.7%	20.0%	6.7%	21.3%	5.5%	17.4%	29.3%	17.3%
2002	\$1,833	\$138	\$33	11.0%	11.6%	11.8%	12.8%	15.7%	14.1%	73.1%	49.9%	73.2%	22.0%	23.0%	19.4%	5.9%	15.2%	9.0%	22.8%	39.2%	24.3%
2003	\$2,842	\$126	\$69	10.6%	10.9%	11.4%	13.6%	17.3%	14.1%	72.9%	51.0%	74.4%	20.3%	23.7%	19.3%	4.2%	7.8%	4.4%	26.8%	45.8%	27.3%
2004	\$1,863	\$102	\$97	11.3%	12.0%	12.6%	13.5%	17.9%	13.4%	68.5%	46.6%	66.0%	21.5%	23.7%	20.9%	3.9%	8.9%	4.6%	30.9%	50.8%	34.5%
2005	\$2,736	\$153	\$201	11.3%	12.1%	11.4%	11.5%	15.3%	10.6%	62.1%	47.6%	56.8%	22.3%	23.2%	25.5%	4.3%	10.4%	5.1%	34.1%	46.2%	34.7%
2006	\$2,910	\$179	\$236	12.0%	12.9%	12.0%	10.3%	13.3%	9.2%	57.5%	46.4%	52.3%	23.3%	23.7%	26.3%	6.2%	13.2%	7.8%	35.3%	42.9%	34.8%
2007	\$6,109	\$530	\$316	11.7%	12.3%	11.7%	9.6%	11.1%	8.9%	57.8%	46.9%	54.3%	23.2%	22.2%	25.6%	8.6%	18.0%	12.5%	31.7%	36.4%	28.1%
2008	\$4,674	\$316	\$219	10.5%	12.4%	10.2%	8.8%	11.3%	8.0%	63.1%	49.4%	57.3%	22.0%	19.9%	23.0%	10.8%	19.6%	15.0%	23.5%	34.9%	23.0%
2009	\$619	\$0	\$18	7.5%	11.8%	8.5%	8.6%	16.9%	9.5%	73.9%	86.1%	70.6%	19.0%	4.1%	20.4%	5.5%	15.2%	4.4%	17.8%	23.4%	22.4%
2010	\$188	-	\$3	6.9%	-	6.1%	9.9%	-	10.1%	79.6%	-	86.6%	20.6%	-	16.9%	3.3%	-	1.9%	13.2%	-	10.8%
2011	\$135	-	\$4	7.2%	-	7.2%	11.5%	-	12.2%	83.6%	-	81.8%	21.4%	-	14.8%	2.2%	-	3.4%	11.5%	-	19.5%
2012	\$150	-	\$4	5.8%	-	7.3%	12.2%	-	18.3%	83.6%	-	82.7%	21.6%	-	19.2%	2.6%	-	1.9%	10.2%	-	21.9%
2013	\$189	\$0	\$4	6.0%	7.2%	6.4%	11.4%	17.9%	12.8%	80.4%	111.4%	81.9%	25.4%	7.8%	16.7%	3.0%	0.6%	7.9%	8.6%	5.3%	12.8%
2014	\$159	\$0	\$2	6.1%	8.8%	6.1%	10.0%	17.4%	12.2%	81.0%	88.3%	81.0%	25.3%	17.1%	26.8%	2.9%	0.0%	1.2%	7.0%	20.8%	9.3%
2015	\$104	-	\$2	5.0%	-	5.4%	8.7%	-	11.6%	83.8%	-	66.9%	21.4%	-	44.4%	3.3%	-	0.6%	5.2%	-	5.3%
2016	\$46	\$0	\$0	4.2%	4.0%	3.1%	7.0%	6.6%	9.0%	84.8%	107.1%	92.7%	18.1%	0.0%	21.1%	2.6%	0.0%	0.1%	5.8%	3.4%	-1.8%
2017	\$8	-	\$0	3.4%	-	5.5%	4.6%	-	13.0%	77.2%	-	87.9%	19.6%	-	5.0%	7.4%	-	0.0%	3.7%	-	25.6%

Source: Fannie Mae, MSCI

6 Prepayment Model

Agency CRT deals are subject to both credit risk and voluntary prepayment risk. As the prices of CRT deals have appreciated greatly over the past five years, driven by strong credit performance, voluntary prepayment modeling has become much more important than previously deemed. The collaterals backing the CRT deals are the same mortgages that are securitized in the traditional agency mortgage-backed securities (MBS). We therefore adopt the same prepayment model as our MSCI Agency Prepayment Model.⁴ This section briefly summarizes the modeling approach on this topic.

Base prepayment speed consists of **housing turnover**, **cashout**, and **curtailment**. **Housing turnover** is the biggest component of base prepayment speed. When a home is sold, the underlying mortgage will be paid off. **Cashout** activity has also been recovering toward the historical average level. The following exhibit shows the total equity cashed out divided by the outstanding balance. **Curtailment** occurs when the borrower, motivated by faster equity building, makes a partial payment to bring down the outstanding loan balance.

Putting all of the pieces together, Exhibit 34 shows the decomposition of the base prepayment speed across different rate incentives. Overall, the total base prepayment speed drops to 6.4 CPR (120 bps out-of-the-money) from 12 CPR (at-the-money). Cashout and rate/term refinance should be dampened quickly as rates rise, while HT stays relatively stable for a mild rise in rates and starts to slow down when the disincentive becomes significant. Curtailment is a relatively small and stable component, showing a moderate lock-in effect. The MSCI Agency Prepayment Model captures these components separately. As the drivers for each component are very different, it is critical to calibrate each component individually and accurately, so the model forecasts can navigate through the ever-changing, multi-dimensional economic sphere.

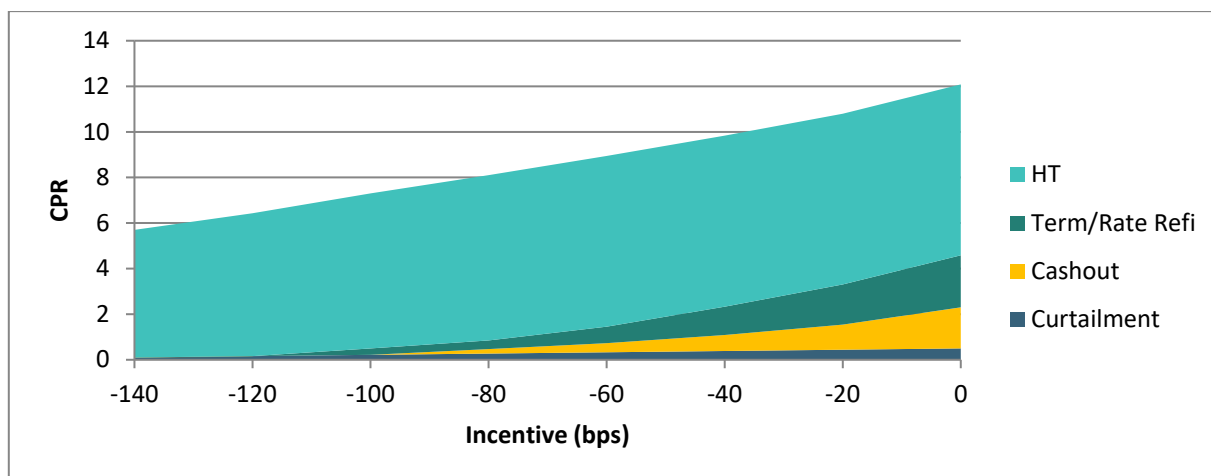
⁴ Yu, Y. (2018) "[MSCI Agency Fixed Rate Base Prepayment Model](#)." MSCI Model Insight. (client access only)

Yu, Y. (2018) "[MSCI agency fixed rate refinance prepayment model](#)." MSCI Model Insight. (client access only)

Yu, Y. and Zhang D. (2019) "[MSCI Current Coupon Models: Model Risk Premium in a Risk-Neutral Model](#)." MSCI Model Insight. (client access only)

Yu, Y. (2019) "[MSCI Primary - Secondary Mortgage Spread Model](#)." MSCI Model Insight. (client access only)

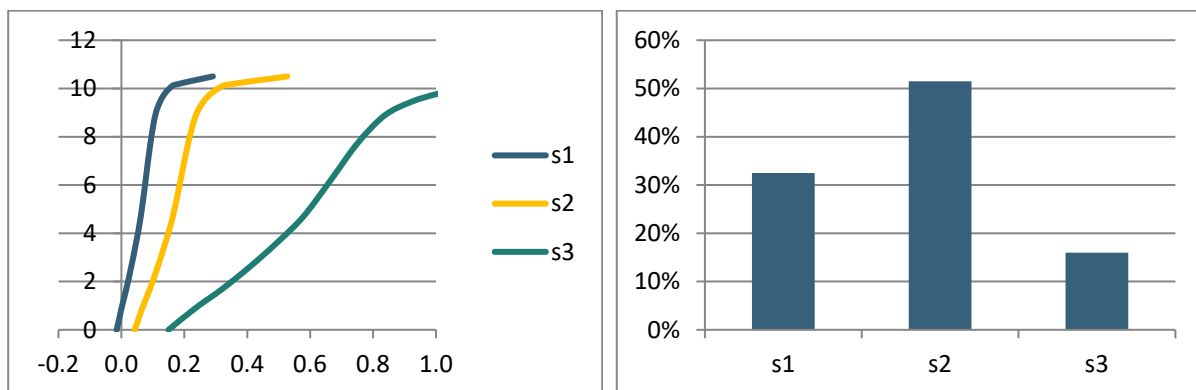
Exhibit 34: Decomposition of base prepayment speed across different rates incentive



Source: MSCI

The refinance prepayment model is driven mainly by borrowers' economic incentive to lower their monthly payments. The most critical component is the refinance s-curve. The MSCI refinance model adopts a dynamic population burnout approach, as shown in Exhibit 35. Each curve represents a different subpopulation among the collaterals. As time goes on, mortgages with higher refinance propensities will retire from the population at a faster pace. The s-curve also interacts with other loan characteristics, such as loan size, credit score, geographic distribution, and so on and so forth. The MSCI agency prepayment model takes advantage of the granularity of the agency's data disclosure.

Exhibit 35: S-curve and initial distribution for the three subpopulations for refinance prepayment



Source: MSCI



CONTACT US

AMERICAS

Americas	1 888 588 4567 *
Atlanta	+ 1 404 551 3212
Boston	+ 1 617 532 0920
Chicago	+ 1 312 675 0545
Monterrey	+ 52 81 1253 4020
New York	+ 1 212 804 3901
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EUROPE, MIDDLE EAST & AFRICA

Cape Town	+ 27 21 673 0100
Frankfurt	+ 49 69 133 859 00
Geneva	+ 41 22 817 9777
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ASIA PACIFIC

China North	10800 852 1032 *
China South	10800 152 1032 *
Hong Kong	+ 852 2844 9333
Mumbai	+ 91 22 6784 9160
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