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Impacts of Down Payment Underwriting Standards on Loan Performance – Evidence from the GSEs and FHA portfolios

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Abstract

Policy discussions are increasingly focused on a return to more conservative mortgage underwriting standards. This study explores the relationship between down payment (loan-to-value ratio or LTV) requirements and loan performance of GSE and FHA mortgages, controlling for borrower characteristics and housing market conditions. Loan performance models are estimated based on cohorts of loans originated between 1995 and 2008. Model parameters are then used to conduct simulations to estimate the marginal or incremental impact of adjusting the down payment requirements on cumulative delinquency and foreclosure rates. Default and prepayment equations are estimated simultaneously using large samples of loans drawn from the universe of loans from the GSE and FHA origination data, which yield parameter estimates that are precise and robust. Serious delinquencies and foreclosures are analyzed separately for different segments of the mortgage market. The study sheds important light on the policy question regarding how down payment requirements should be understood in conjunction with other underwriting guidelines. Specifically, we present simulation results that demonstrate the relationship between down payment standards and loan performance by borrower credit score category and debt-to-income ratio category. We found that the lifetime delinquency and foreclosure rates increase monotonically and nonlinearly as original LTV rises. The magnitude of the impacts is sensitive to the borrower's credit score and debt-to-income levels. Furthermore, there are appreciable differences across the GSE and FHA segments of the mortgage market in terms of borrower responses.

1. Overview

Since the collapse of the housing bubble, there has been increasing attention on the terms available to mortgage borrowers, with a focus on preventing a repeat of our current foreclosure crisis. The goal is to not just get borrowers into owner occupied housing, but to keep them there. Hence, we use the term "sustainable mortgage."

One key dimension for limiting default risk at the time a loan is underwritten is the down payment requirement. *Ceteris paribus*, higher down payments result in lower default risk mortgages. While the down payment is an important dimension of mortgage underwriting, it is not the sole determinant of default risk. The effect of changes in the down payment requirement may be influenced by the stringency of other variables used in the underwriting process. A key variable is the credit score for the borrower, often calculated using models developed by Fair Isaac Corporation (FICO) at loan origination.

The purpose of this paper is to evaluate the extent to which higher down payments produce more sustainable mortgages. Specifically, we used hazard models to estimate the relationship between down payment (loan-to-value ratio or LTV) requirements and loan performance, controlling for a wide array of borrower/loan characteristics and housing market conditions. The regression model parameters were then used to conduct simulations to examine the marginal or incremental effect of LTV at origination on loan performance outcomes. The simulations yielded a set of easy-to-understand results that allow us to quantify the relationship between down payment standards and loan performance by borrower credit score and debt-to-income ratio category. These estimates offer a more complete view of the down payment-loan performance relationship than simple summary statistics and cross tabulations would provide.

The study focuses on the segments of the residential mortgage market served by the two housing Government-Sponsored Enterprises (GSEs) – Fannie Mae and Freddie Mac – and the Federal Housing Administration (FHA). This includes the universe of single-family mortgages purchased by the GSEs or insured by the FHA. The subprime and Alt-A segments of the market are not a focus of this study because of our focus on sustainable mortgages.

The down payment requirements vary across the GSE and FHA markets. Loans purchased by the GSEs typically require a 20 percent down payment; those with less than a 20 percent down payment require mortgage insurance or a second lien. FHA mortgages, on the other hand, are associated with a less stringent down payment requirement. Many FHA borrowers pay only 3 to 4 percent of the purchase price as down payment.

The layout of the rest of the paper is as follows. We begin with a brief literature review of mortgage default modeling, with special attention paid to the limited literature focused on down payments. This is followed by a section on the GSE and FHA data used to estimate the mortgage termination models. The next section lays out the default and prepayment models used to estimate the effect of down payments on cumulative delinquency and foreclosure rates. These models are then used to generate a

wide variety of simulations relating down payment requirements to projected delinquency and foreclosure rates.

2. Literature Review

While there is an exhaustive literature on mortgage termination models, there are few papers that focus exclusively on the relationship between borrower's down payment and loan outcomes. This study aims to fill in this gap in the literature. Most discussion in the default modeling literature considers mark-to-market LTV ratio, which is the combination of the effects of the initial down payment and subsequent house price appreciation or, more recently, depreciation. Excellent reviews of the mortgage default literature may be found in Vandell (1995), the Government Accountability Office's (GAO) report on low down payment mortgages (2005), and Quercia (1992). The summary in the GAO report is typical – equity, in the form of either initial down payment, or subsequent appreciation, and the borrower's credit capacity, as measured by a borrower credit score, are nearly universally found to be the two key drivers of default risk.[1] Other variables are also found important in several studies, such as debt-to-income ratios, accumulated reserves, loan amortization terms, and loan product type.

The effect of the initial equity (the complement of the down payment) on default was first assessed in von Furstenburg (1969). Using a simple linear regression model, annual default rates of FHA mortgages were regressed on the down payment amount (one minus original LTV), mortgage age, and its squared term. The purpose was to measure the partial default elasticity with respect to the down payment amount. The estimated regression coefficient for the down payment amount was found to be negative and statistically significant across year cohorts and maturity term types, indicating that default rates fell with a rise in the down payment amount.

Some subsequent work does not distinguish between initial and accumulated equity. A few papers include separate variables for original LTV and subsequent equity accumulation. For example, Deng, Quigley, and Van Order (1996) used loan-level data from Freddie Mac to estimate default and prepayment equations in a proportional hazard framework, with the initial LTV as one of the explanatory variables. The authors found that default decisions were sensitive to both LTV at loan origination and the subsequent course of housing equity. The results also indicated the importance of trigger events such as unemployment and divorce in affecting default and prepayment behavior. With simulations, the model parameters were then used to analyze the program costs of offering low (in particular, zero) down payment mortgages to middle- and low-income borrowers. They found that the magnitude of the costs depends on the assumption of future house price appreciation.

The loan termination models built by Deng, Quigley, and Van Order (2000) also included original LTV, aside from the put option and call option variables the authors were testing in a contingent claims framework. Default and prepayment decisions were theorized as the exercise of financial options by the

[1] Credit capacity here refers to both the borrower's willingness to pay and ability to pay.

borrowers in the mortgage contracts. Mortgage default occurs if the borrower exercises the put option when the market value of the mortgage equals or exceeds the value of the house; in such circumstances, the put option is considered to be "in the money." Similarly, the borrowers exercise the call option to prepay their mortgages when the market value of the mortgage equal or exceeds the book value of the mortgage. The original LTV was used to control for asymmetric information at loan origination because, the authors argued, riskier borrowers choose to take out high LTV loans.

GAO's study (2005) of FHA down payment assistance programs examined the down payment (in terms of original LTV) as a default predictor, over and above the effect of mark-to-market LTV. It found that zero down payment mortgages had extremely elevated default propensities, especially in Metropolitan Statistical Areas (MSAs) with flat housing prices. It also found that the source of the down payment mattered – a down payment from the borrower's own resources reduced default by more than the same sized down payment provided by a relative or a government program. FHA's own work in its actuarial studies (for example, HUD 2010) also found an important effect of down payment source. Kelly (2008) also stressed the importance of down payment source and found that even a small amount of down payment would substantially reduce default, when compared to loans that had zero down. Ben-David (2011) finds similar results.

Other recent literature considers the stability of default models. Demyanyk and Van Hemert (2011), and An et al. (2011) found that simple default models are unstable, and suggested the need to include cohort dummies, and even cohort slope dummies, in regressions, to capture for the effects of unmeasured changes in underwriting quality over time. Kelly (2009) considered the value of appraisals and automated valuation models as additional signals of initial equity. Ehul (2009) looked at securitization, and the extent to which an originator's ability to offload credit risk could influence underwriting and subsequent default propensities. LaCour-Little (2009) found substantially elevated default rates for loans with little or no borrower provided documentation (so-called Liar's Loans).

3. Sources of Data

There are two primary sources of data used in this paper. The source of data for the GSEs' market segment is the Enterprises' Historical Loan Performance (HLP) data maintained by FHFA. The HLP data include loan-level information on all mortgages Fannie Mae and Freddie Mac acquired or guaranteed since the late 1970s. The database includes detailed loan history records (month-by-month payment amounts) and a wealth of initial loan characteristics. Loan product type (fixed vs. adjustable), initial loan balance, sales price of the house, initial payment amount, borrower's income, documentation level, and FICO borrower credit scores are all provided. The date the loan was originated and the location of the mortgaged property are also provided. The loan history includes indicators for full prepayment and the date of prepayment, indicators for spells of serious delinquency (90-day plus), and final loan disposition outcomes. Detailed payment histories are also included. While we have data as far back as 1979, borrower credit scores only became ubiquitous around 1995. For this study, therefore, we used originations from 1995 to 2008. Performance of the loans is observed from origination to liquidation

(prepayment or foreclosure) or through December 31, 2012 if still performing. Loans originated in 2009 and after were not used in the study due to the lack of time to observe their performance.

For the FHA segment of the market, we used data from FHA's single-family data warehouse (SFDW). Similar to the HLP data, the SFDW data include loan-level information on the origination and performance of mortgages insured by FHA. Compared to the HLP data, the FHA database contains a less detailed loan history, but it includes a richer set of information on the borrowers. The file contains the main underwriting variables, such as borrower credit score, initial loan balance, and sale price of the house, along with indicators for the source of the down payment (borrower, seller, government program, etc.). All FHA loans have full borrower documentation. We also have indicators for claim termination (FHA pays insurance for a credit loss, usually as a result of a foreclosure), non-claim termination (a prepayment), and the date that a 90-day delinquency episode starts, along with information on how the delinquency spell was resolved. However, for the FHA data we do not have detailed monthly payment history. Because FHA only began the routine collection of borrower credit scores in 2004, we have limited the evaluation of FHA mortgages to loans originated from 2004 to 2008. As with the GSE mortgages, FHA loan performance is observed through December 2012. Originations from 2009 and 2010 were not used due to the lack of sufficient loan performance history.

For estimation purposes, we merged the GSE and FHA data with quarterly data from FHFA on MSA- and state-level house price indexes, data from Bureau of Labor Statistics (BLS) on state-level unemployment rates, data from the Federal Reserve on Treasury yields for 2- and 10-year maturities, and data from Freddie Mac on prevailing mortgage interest rates (Primary Mortgage Market Survey). For simulating delinquency and foreclosure rates, we used forecasts of house prices, interest rates, and unemployment rates from Moody's Analytics. We primarily relied on Moody's "base case" projection scenario, but for sensitivity analysis we have also incorporated alternative Moody's forecasts, namely a "pessimistic case" that assumes a slow recovery, and falling house prices.

In terms of mortgage product type, our analysis focused on traditional 30-year fixed-rate mortgages, as this is the most common product type and represents the largest share of the total origination volume each year. We further limited the analysis universe to home purchase mortgages. In other words, refinances were excluded. In addition, we excluded from the analysis "investor loans" and loans classified as Alt-A by the GSEs. These loan types were excluded because they had underwriting requirements and performance history that were different from those of the owner-occupied home purchases. The underlying mortgage performance model in terms of the relevant variables and model parameters would most likely differ significantly for these loan types. Therefore, excluding them from the analysis would allow us to avoid confounding factors and arrive at a more precise estimate of the effect of the down payment on loan outcomes.

To construct the estimation sample, we draw a 17 percent random sample of loans from the FHA analysis universe and 5 percent random sample from the GSE analysis universe.[2] The differential sample rates were used to ensure that the estimation sample size per year is in the same magnitude across the two market segments. Exhibit 1 shows the number of loan origination volumes for the analysis universes and estimation samples, separately by year and mortgage market segment (FHA vs. GSE).

Exhibit 1: Number of Loan Originations, by Market Segment: 1995-2008
30-Year Fixed-Rate Home Purchase Mortgages

Analysis Universe

Year of Origination	Market Segment	
	FHA[a]	GSEs
1995	.	1,112,034
1996	.	1,167,487
1997	.	1,175,676
1998	.	1,773,979
1999	.	1,715,499
2000	.	1,626,949
2001	.	1,919,491
2002	.	1,813,925
2003	.	1,839,304
2004	467,297	1,488,681
2005	327,872	1,592,273
2006	296,698	1,642,807
2007	305,538	1,960,630
2008	803,296	1,310,068
Total	**2,200,701**	**22,138,803**

Estimation Sample[b]

Year of Origination	Market Segment	
	FHA[a]	GSEs
1995	.	24,334
1996	.	47,959
1997	.	54,114
1998	.	77,309
1999	.	82,451
2000	.	73,663
2001	.	89,991
2002	.	85,887
2003	.	86,585
2004	42,499	72,183
2005	55,821	76,439
2006	54,191	79,903
2007	56,575	93,041
2008	154,380	70,531
Total	**363,466**	**1,014,390**

Source: FHFA
Notes: [a]1995-2003 cohorts were excluded because borrower FICO scores are not available.
[b]Excluded mortgage records with missing values on any covariates used in the loan termination models.

4. Loan Performance Model

Two loan performance measures are analyzed separately in this study:

- Foreclosure completion
- 90-day delinquency[3]

[2] The estimation sample excluded mortgage records that contain missing values in any of the variables we used in the loan termination models.
[3] We focused on the incidence of a borrower becoming 90-day delinquent the *first-time* since loan origination.

90-day delinquency is a commonly used benchmark in the mortgage industry for serious delinquency, as loss mitigation/workout strategies and foreclosure proceedings usually start once a loan has reached the 90-day delinquency mark. Of course, not all loans becoming 90-days delinquent eventually end in foreclosure. The measure nonetheless serves as a good early-warning indicator for adverse outcomes, as the link between 90-day delinquency and foreclosure is strong.

Foreclosure completion is a measure aimed at capturing the adverse outcome that the loan is being liquidated and that the borrower eventually loses his/her home in the foreclosure process. For loans in the GSE portfolio, we defined foreclosure completion as: (1) short sales (also called pre-foreclosure sales); (2) deeds-in-lieu; (3) third-party sales at the foreclosure sale/auction; (4) loans that ever entered the real-estate owned (REO) inventory; and (5) charge-offs in lieu of foreclosure. For the FHA segment of the market, we equated foreclosure completion as a claim termination. That is, all loan terminations eventually resulted in a claim to the FHA mortgage insurance fund. It signifies the end of the foreclosure process when the servicer/lender transfers the title of the property to HUD/FHA. It is worth noting that this definition of foreclosure completion is not exactly comparable to the one used for the GSE loans. Due to limitations of data provided by FHA, we were not able to construct a foreclosure completion measure that is entirely consistent across the two segments of the market.[4]

To explore the relationship between loan performance and underwriting standards, we built hazard models using historical loan-level data that explain loan performance based on loan characteristics and macroeconomic drivers. Specifically, a "competing risk" model framework was used where default and prepayment probabilities were estimated jointly. We have estimated two default/prepayment competing risk models: one for foreclosure completion and one for 90-day delinquency.

Mortgage lives were modeled as competing risks of termination via monthly prepayment or default hazards, estimated simultaneously using a multinomial logit model. Each record used in the estimation represented a loan-month observation since origination. Jenkins (1995) has demonstrated that this model set up is equivalent to estimating a discrete-time competing hazard model. Key advantages of hazard models are that they are useful for projection/forecasting and that they take duration dependency into account. Separate models were developed for the GSE and FHA segments of the market.

[4] Unlike 90-day delinquency, foreclosure completion depends on an array of factors well beyond the scope of a model for borrower behavior. For example, foreclosure completions have been impacted substantially in the last few years by state-level foreclosure moratoriums, court backlogs, and other legal challenges. These factors are difficult to account for in our regression models.

4.1 Explanatory Variables

For each mortgage market segment, a common set of explanatory variables was used across the two measures of performance outcomes. The GSE and FHA models differed slightly in terms of the set of explanatory variables used, as explained below.

- **Mortgage Age (Seasoning)**. Age since origination was captured in a series of linear spline variables.[5] We picked the knots (or "cut points") for the spline function differently across the FHA and GSE models.
- **Seasonality**. A series of monthly dummies were used to represent the season of the loan-month records. The dummy for the month of January was omitted and served as the reference category.
- **Origination Cohort (Vintage)**. Cohort effects were captured by a series of cohort dummies indicating the calendar year of loan origination.
- **Borrower FICO Score at Origination**. This was represented by a series of spline variables. The knots are: 620, 660, and 700.
- **Loan-to-Value (LTV) Ratio at Origination.** This is a key variable for this study. One minus LTV represents the down payment amount. For the GSE data, we were able to obtain the combined LTV (i.e., first lien, plus any subordinate liens acquired by the GSEs) as of the time of loan origination. However, it is worth noting that the data reflect the combined LTV only in situations where the related second lien is simultaneously acquired or guaranteed by the same GSE.[6] In other words, the LTV in the data does not always reflect the cumulative loan balances of all mortgages associated with the property. The FHA database reports LTV for the first lien only. Nonetheless, for home purchases, most of the FHA borrowers did not have a second lien at origination.

  To capture non-linearity effects, we entered the LTV into the regression equation as a series of piecewise linear spline variables. The knots are: 70, 80, 90, and 95.
- **Front-end Debt-to-Income (DTI) Ratio at Origination**. This is the ratio between total monthly mortgage payment amount and total monthly household income, entered as linear splines. The knots are: 0.25, 0.31, and 0.35.

[5] To capture non-linearity, linear splines allow us to estimate the relationship between the dependent variable Y and an explanatory variable X as a piecewise linear function, which is a function composed of linear segments. The linear segments are arranged so that they are joined at knots x1, x2, x3, etc. One linear segment represents the function for values of X below x1; another linear segment represents the function for values of X between x1 and x2; and so on. For variables used in the study, we tried to pick the knot points that are logical or represent meaningful divisions in the data. For example, for variables using in the underwriting process such as borrower FICO score, debt-to-income ratio, and LTV, the knot points included the thresholds of these variables used in the various underwriting regimes. For variables such as mortgage age and other financial variables, we picked the knot points so that the underlying observations would be distributed approximately even across the spline segments.

[6] In additional, the data do not capture information on any subordinate liens originated since the origination of the first lien.

- **Back-end Debt-to-Income (DTI) Ratio at Origination**. This is the ratio between total debt payment amount and total monthly household income, entered as linear splines. The knots are: 0.30, 0.35, and 0.42.
- **Unpaid Principal Balance (UPB) at Origination**. The variable is the original mortgage amount, adjusted to constant dollars in 2013. It is represented with a set of linear splines, with knot points at $100,000, $200,000, and $300,000.
- **Interaction of Mark-to-Market (Current) LTV and FICO Score at Origination.** The mark-to-market LTV (MTMLTV) measures a borrower's current house equity position. For each of the subsequent loan-month records since origination, we calculated the current LTV value as follows. We first computed the UPB amount for each loan-month record using the loan terms and mortgage payment formula. Next, the house value was adjusted using FHFA's MSA- and state-level House Price Indexes (HPI).[7] Finally, we divided the UPB by the updated house value.

  The MTMLTV and FICO score were each specified as four linear spline variables. The knots for the MTMLTV are 0.8, 1.0, and 1.25, while the knots for the FICO are 620, 660, and 700. We entered the pair-wise products of these spline terms into the regression model. They represent a total of sixteen variables. This specification allows the model to estimate the effect of MTMLTV on loan performance differently for borrowers with varying credit backgrounds.
- **Spread at Origination (SATO)**. This variable measures the difference between a loan's contract mortgage rate and prevailing rate, as reported by Freddie Mac's PMMS survey at the origination month. The spline format of the variable was used in the models, with knot at 0.17.
- **Interaction of Refinance Incentives (Spread) and Burnout Factor.** Following Dunsky and Ho (2007), we used this set of variables to model the borrower's decision to prepay (refinance). The refinance incentive variable measured the ratio between the prevailing mortgage rate at origination and the prevailing rate at each of the subsequent months.[8] We used the historical rates for 30-year fixed-rate mortgages published by Freddie Mac's PMMS as a proxy for the prevailing mortgage rates. The burnout factor variable, a time-varying covariate, was calculated as the significantly positive refinance spread cumulated over the life of the mortgage, reflecting missed or forgone refinance opportunity.[9]

[7] State-level HPI were applied to housing units located outside of an MSA.

[8] Alternatively, the variable could be specified as a simple difference, rather than a ratio. In either format, we do not think the LTV-default relationship would be sensitive to this set of variables, which are meant to capture the borrower's prepayment decision. We have estimated the regressions with both formats of the variables and found no materialized impact on the other regression coefficients and the study's findings.

[9] Specifically, the refinance incentive or spread was calculated as:

$$Refinance\_spread_{i,t} = \frac{PMMS_{i,t=0}}{PMMS_{i,t}}$$

The burnout factor was computed as:

$$Burnout_{i,t} = \sum_{t=0}^{T} MAX\left(\frac{PMMS_{i,t=0}}{PMMS_{i,t}} - 1.1, 0\right)$$

The refinance spread and burnout factor were each specified as three linear spline variables, with knot points at 1.15 and 1.25 for the refinance spread and 0.3 and 0.8 for the burnout factor. We entered the pair-wise products of these spline terms into the regression model. They represent a total of nine variables.

- **Yield Curve Spread**. A time-varying covariate, this was calculated as the difference between the 2-year and 10-year Constant Maturity Treasury, lagged one month.
- **Census Division**. To control for the effect of regional housing market, we included indicators for the eight Census Divisions (South Atlantic was omitted and served as the reference category).
- **Metro vs. Non-metro Location**. This indicator was used to identify borrowers located in MSAs, defined by the Census Bureau.
- **State Laws**. State laws can have an impact on the borrower's decision to default or prepay. The consideration here is whether foreclosure is carried out through a judicial or non-judicial process. A judicial foreclosure process requires lenders to process foreclosure filings through the court system. Non-judicial foreclosures are generally simpler and quicker. Some states offer both, although in such states non-judicial proceedings are generally used more frequently. In other states the judicial process is the only option. A small number of states do not have a judicial foreclosure process. Also, some states allow the lender or insurer to recover losses by filing a lien against assets of the borrower other than the house that secured the mortgage. States with laws blocking deficiency judgments provide added protection for the borrowers; we called these states anti-deficiency states. Combining these two types of state laws, we grouped the states into four mutually exclusive categories: (1) non-judicial and no anti-deficiency; (2) non-judicial and anti-deficiency; (3) judicial and no anti-deficiency; and (4) judicial and anti-deficiency.[10] The first category was omitted and served as the reference category in the regressions.
- **Unemployment Rate (State Level).** Entered as linear splines with a knot at six percent, unemployment rates were lagged one month in the regressions.
- **Sources of Down Payment Funds**. This variable is available only in the FHA data. The four mutually exclusive categories are: (1) buyer/owner; (2) family/relative; (3) non-profit; (4) government or other. We omitted the first category as reference in the model.
- **Existence of a Second Lien**. This variable is available only in the GSE data. We flagged any mortgages with a subordinate lien as of the time of origination.
- **Number of Housing Units**. We included a dummy variable in the model to control for the effect of houses with more than one unit.
- **Housing Structure Type**. A dummy variable was used to flag the condominium unit type.

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where 1.1 was assumed to reflect the refinance transaction cost. That is, we assumed that a refinance opportunity would occur whenever the original PMMS rate exceeds the prevailing PMMS by 10 percent. See discussion in Dunsky and Ho (2007).

[10] For states that allow both judicial and non-judicial foreclosure, we classified them as non-judicial state. Our classification follows Pence (2006) and the information provided by the non-profit web site www.foreclosurelaw.org.

4.2 Regression Parameter Estimates

Regression parameter estimates are reported in Appendix A. Because of the "stacked" loan-month records and multinomial logit set up, the estimated coefficients are difficult to interpret. Our use of the piecewise linear splines and interaction terms in the models have added another layer of complexity to the interpretation. Therefore, to examine the marginal or incremental effect of LTV at origination on loan performance outcomes, we conducted simulations on a set of synthetic loans using the regression coefficients. The setup and results are described in Section 5.

4.2 Goodness of Fit of the Models

To check the goodness of fit of our models, we compared the observed and model-predicted conditional probability of the outcomes in terms of monthly average. The comparisons are presented in Appendix B as a series of graphs. For example, Exhibit B1 plots, for the GSE market segment, the monthly average conditional 90-day delinquency rate by loan age. Exhibit B2 shows the rate by calendar date. Similar plots were done for the other performance outcomes and for the FHA market segment. Overall, the model-predicted rates track the observed rates fairly well.

5. Simulations

To quantify the lifetime effect of LTV at origination on loan outcomes, we conducted simulations using the regression coefficients and a set of synthetic loan-month records. The loan-month records were constructed in such a manner that there are variations across records for the variables of interest (in particular, LTV, FICO score, and front-end DTI), while other loan and borrower characteristics are held constant throughout. This setup allows us to explore, *ceteris paribus*, the marginal or incremental impacts of changing the LTV (down payment) underwriting requirement on loan performance.

The set of synthetic loan-month records were constructed with the following loan and borrower characteristics.

1. Originated in January 2013.
2. Original mortgage amount is $200,000.
3. Mortgage rate at origination is 5 percent.
4. Borrower FICO score at origination varies from 620 to 740 by an increment of 40.
5. LTV at origination varies from 70 percent to 100 by an increment of 1.
6. Front-end debt-to-income (DTI) ratio is set at 31 percent and 45 percent.
7. Back-end debt-to-income (DTI) ratio is set at 45 percent.
8. Source of down payment is self-financed (only relevant to the FHA segment).
9. No second lien.
10. Structure contains one housing unit.

11. Non condominium structure type.
12. Located in metropolitan area.
13. One loan per state (50 states plus the District of Columbia), per loan/borrower characteristic.

This setup generated a total of 12,648 unique synthetic loans. For each loan, we then generated monthly records for seven years following origination. This resulted in a total of 1,062,432 loan-month records.

It is important to note that the varying loan-level characteristics are #4 (borrower FICO score), #5 (original LTV), and #6 (front-end DTI ratio) across this set of loans, aside from the state location.[11]

To project the future performance of this set of loans, we used the estimated regression coefficients from the loan termination models described in Section 4 to compute the conditional prepayment probability and default probability for each loan-month record.[12] For macro-economic variables such as future mortgage interest rate, Treasury yield (2- and 10-year maturity), state-level unemployment rate, and the house price growth path, we utilized the baseline forecast scenario produced by Moody's Analytics. Next, the conditional probabilities by loan-month were converted into cumulative probabilities.[13]

The outcomes of interest are:

- Predicted seven-year cumulative foreclosure completion rate
- Predicted seven-year cumulative 90-day delinquency rate

We analyzed cumulative foreclosure completion and delinquency rates for the first seven years because loan terminations happening in that duration are more likely due to underwriting variables rather than other trigger events. As a loan ages beyond seven to ten years old, it becomes increasingly difficult to tease out other confounding factors that would lead to a loan termination. In addition, in most cases,

[11] Changes in the macro-economic variables are tied to the state location of the loan.

[12] For the cohort effect parameter in the regression model, we assumed these loans have the same coefficient as the 2004 cohort because 2004 represented a typical year. The objective was to avoid picking a cohort coefficient that is associated with the onset or aftermath of the 2007/2008 financial crisis.

[13] Specifically, let us define:

D(t) = conditional default probability for loan-month record at month t
P(t) = conditional prepayment probability for loan-month record at month t

S(t) = surviving probability for loan-month record at month t
= S(t-1) - (P(t) + D(t))*S(t-1)
CUMDEF(t) = cumulative default probability for loan-month record at month t
= D(t)*S(t-1) + CUMDEF(t-1)
CUMPRE(t) = cumulative prepayment probability for loan-month record at month t
= P(t)*S(t-1) + CUMPEF(t-1)
where S(0)=1 , CUMDEF(0)=0 , and CUMPEF(0)=0.

the cumulative rates tend to taper off or flatten out beyond the first 7 years. In other words, the simulation results would most likely be similar if we extend the forecast period.[14]

It is important to note that our measure of foreclosure completion and delinquency rates is different from the ones commonly reported in the popular press where the rates are defined as the share of loans in foreclosure (or in delinquent) among the loans that are still outstanding. Our measure represents the cumulative or lifetime probability of a loan becoming delinquent (or reaching foreclosure completion).

For each outcome measure, separate estimates were produced for the GSE and FHA segments of the market.

For the purpose of exposition, we will focus our presentation on the results for foreclosure completion. However, we did test the sensitivity of our findings to the alternative metric. Findings on the 90-day delinquency rate are presented in a later section and the appendix.

To explore the sensitivity of our estimates to the macro-economic forecasts, we also conducted the analysis using an alternative scenario forecast called "protracted slump." The cumulative delinquency and foreclosure completion rates that we simulate are based on scenarios with flat-to-rising interest rate environments, so that the effect of prepayment on reducing observed default rates is muted. A loan that prepays via a refinancing two years after origination cannot be observed to default three years after origination, although the (unobserved) new refinancing loan might fail.

To fix ideas and isolate overall marginal effects, our analysis focused on arriving at national level estimates. To do so, we weighted the synthetic loan records by state-level frequency weights. The weights were derived from the 2010 decennial Census using the count of non-vacant owner-occupied housing units at the state level. The same set of weights was used for both the GSE and FHA segments of the estimates.

5.1 Results on Lifetime Foreclosure Completion Rate

5.1A LTV-Foreclosure Relationship and Its Sensitivity to Borrower FICO Score

Using the regression coefficients and the synthetic loan records, Exhibit 2 depicts the relationship between original LTV and cumulative foreclosure completion rate, holding all other borrower and loan characteristics constant with macroeconomic variables varying throughout the life of the mortgages. In particular, borrower FICO score and front-end DTI are set at 620 and 31 respectively. The analysis was conducted separately for the FHA and GSE segments of the market. It shows that, across market

[14] Unlike the "marginal effect" estimates commonly reported in many of the econometric software packages, which capture the instantaneous (monthly) effect of the regression coefficients, our simulation approach yields estimates that represent the "total effect" of original LTV on loan performance outcomes throughout the life of the loans.

segments, as original LTV increases, the lifetime foreclosure rate rises monotonically.[15] The first column shows that, for example, for the GSE loans, as original LTV increases from 70 to 100, the foreclosure rate climbs progressively from 5.66 percent to 19.77 percent. GSE borrowers appear to have a higher foreclosure rate compared to borrowers in the FHA market segment with the same original LTV. As noted above, this is an artifact of our use of different foreclosure measures between the two market segments.

To see the impact of original LTV on loan outcome, in the second column of each panel we present the foreclosure rate changes in *ratio* format, where the results are shown relative to the baseline foreclosure rate for loans with 80 percent LTV at loan origination. That is, they are expressed as multiples of the baseline rate. These estimates provide a convenient way to see the loan performance impact of adjusting the LTV requirement, *ceteris paribus*. The Exhibit indicates that, for example, the foreclosure rate is 9.20 percent for a GSE loan with 80 percent LTV. If the same loan was underwritten with 90 percent LTV, the foreclosure rate would be 1.48 times the baseline level. Alternatively, if the same loan was underwritten with 70 percent LTV, the foreclosure rate would be 0.61 times the baseline level. So apparently the LTV- foreclosure rate relationship is nonlinear. This is especially the case for the FHA segment. When the original LTV is changed from 80 to 70, the foreclosure rate would be 0.72 times the baseline level. However, if we adjust the original LTV by the same increment in the other direction – from 80 to 90, the foreclosure rate would be 1.62 times the baseline level. This wider ranger of changes seems to indicate that foreclosure rates are more sensitive or responsive to LTV changes in the FHA than in the GSE segment of the market.[16]

Exhibit 2: Relationship Between Average Cumulative Foreclosure Completion Rate and Original LTV

Moody's Baseline Economic Scenario

FICO at Origination = 620; Front-end DTI=31; Baseline LTV = 80

	Market Segment			
	GSE		**FHA**	
LTV at Origination	Foreclosure Rate	Ratio to Baseline	Foreclosure Rate	Ratio to Baseline
70	5.66%	0.61	3.54%	0.72
80 (Baseline)	9.20%	1.00	4.95%	1.00
85	11.26%	1.22	6.33%	1.28
90	13.66%	1.48	8.03%	1.62
95	16.55%	1.80	12.41%	2.51
100	19.77%	2.15	14.00%	2.83

Source: FHFA

[15] Henceforward, foreclosure rate means cumulative or lifetime foreclosure completion rate, unless stated otherwise.

[16] Some of this difference across market segments could be result of an attenuation problem of how the combined LTV is reported in the data. The measurement errors (under-reporting) of original LTV is particularly acute for GSE borrowers because of the data issue of incomplete second lien coverage mentioned in the earlier section. If the coverage for the second liens were more complete, some of the GSE loans with 80 LTV would actually be 90 or 95 LTV. Therefore, it is not surprising there is less dramatic effect of higher observed LTVs.

For GSE loans, as original LTV rises from 80 to 100, foreclosure rates would more than double (2.15 times baseline). On the other hand, when original LTV is changed from 80 to 100 for FHA loans, foreclosure rates would increase by almost threefold (2.83 times baseline).

Exhibit 3 repeats the same analysis, separately, for borrowers with four FICO score levels: 620, 660, 700, and 740. The objective of this analysis is to investigate whether the LTV-foreclosure rate relationship remains the same across borrowers with different credit capacity. For this analysis, the DTI ratio was held constant at 31 percent. Once again, the changes in foreclosure rate are presented in ratio format.

The table reveals that, holding LTV constant, borrowers with a lower FICO score are associated with a higher foreclosure rate. This is consistent across the GSE and FHA market segments. When expressed as a multiple of the baseline rate, the foreclosure rate grows steadily with LTV in each FICO class. This is true for both the GSE and FHA markets. For example, for GSE borrowers across the four FICO classes, foreclosure rate of loans with LTV 100 is about 2.2 times the rate of LTV 80.

Exhibit 3: LTV-Cumulative Foreclosure Completion Rate Relationship, by FICO Score at Origination

Moody's Baseline Economic Scenario

Front-end DTI=31; Baseline LTV = 80

	GSE Market Segment			
	FICO Score at Origination			
LTV at Origination	620	660	700	740
80	9.20%	6.10%	4.54%	2.85%
Ratio Between Foreclosure Rate of LTV=80% and Foreclosure Rate of Other LTV Categories				
70	0.61	0.62	0.62	0.63
85	1.22	1.22	1.22	1.21
90	1.48	1.48	1.49	1.47
95	1.80	1.82	1.83	1.81
100	2.15	2.21	2.24	2.26

	FHA Market Segment			
	FICO Score at Origination			
LTV at Origination	620	660	700	740
80	4.95%	3.40%	2.37%	1.37%
Ratio Between Foreclosure Rate of LTV=80% and Foreclosure Rate of Other LTV Categories				
70	0.72	0.71	0.71	0.73
85	1.28	1.28	1.28	1.27
90	1.62	1.62	1.64	1.60
95	2.51	2.53	2.58	2.55
100	2.83	2.86	2.92	2.93

Source: FHFA

Exhibit 3 reveals that – as a multiple of the baseline rate – the rate of foreclosure grows similarly for the four FICO brackets. This nonetheless does not mean that the growth in the foreclosure rate is the same across the four FICO groupings. In fact, the absolute rate of foreclosure rises with LTV much more dramatically for borrowers with lower FICO scores than for borrowers with a higher FICO. Exhibit 4 shows this sensitivity by reporting the *absolute difference* in foreclosure rate instead of the ratio of the rates. The Exhibit indicates that the same magnitude of LTV changes at loan origination would result in different foreclosure rate changes across borrowers with different FICO scores. For instance, if LTV was raised from 80 percent to 95 percent for borrowers with a FICO score of 620 in the FHA market segment, the foreclosure rate would increase by 7.46 percentage points. In comparison, the same change in LTV would result in an increase of foreclosure rate by only 2.12 percentage points for borrowers with a FICO score of 740.

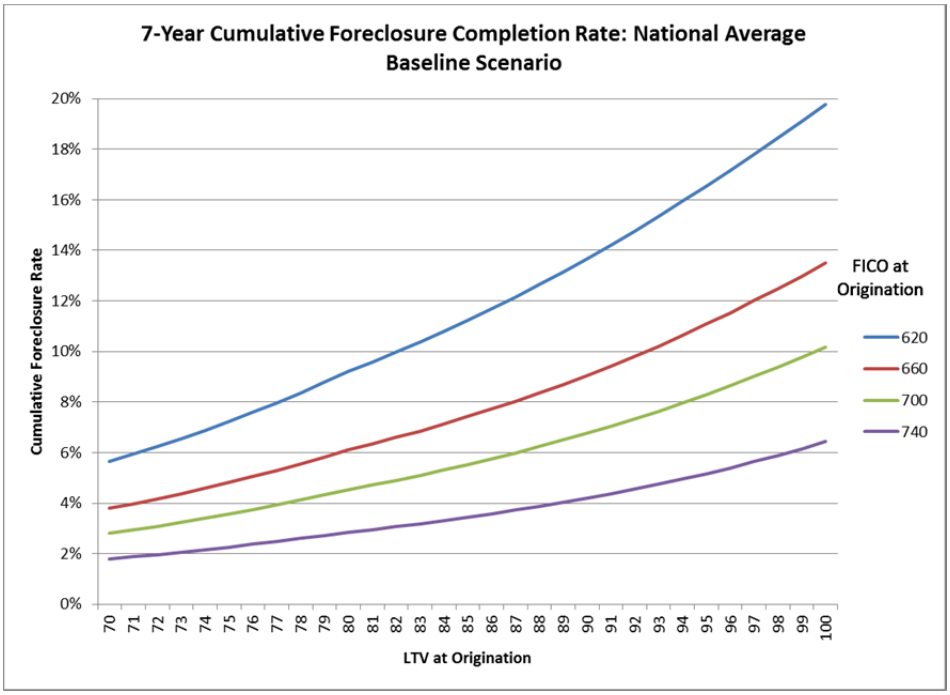
Exhibit 4: LTV-Cumulative Foreclosure Completion rate Relationship, by FICO Score at Origination
Percentage Point Difference Estimates
Moody's Baseline Economic Scenario
Front-end DTI=31; Baseline LTV = 80

	GSE Market Segment			
	FICO Score at Origination			
LTV at Origination	620	660	700	740
80	9.20%	6.10%	4.54%	2.85%
Percentage Point Difference Between Foreclosure Rate of LTV=80% and Foreclosure Rate of Other LTV Categories				
70	-3.55%	-2.31%	-1.73%	-1.06%
85	2.02%	1.31%	0.99%	0.59%
90	4.46%	2.95%	2.23%	1.35%
95	7.35%	4.98%	3.77%	2.32%
100	10.57%	7.41%	5.62%	3.58%

	FHA Market Segment			
	FICO Score at Origination			
LTV at Origination	620	660	700	740
80	4.95%	3.40%	2.37%	1.37%
Percentage Point Difference Between Foreclosure Rate of LTV=80% and Foreclosure Rate of Other LTV Categories				
70	-1.41%	-0.97%	-0.69%	-0.37%
85	1.37%	0.95%	0.68%	0.37%
90	3.08%	2.12%	1.51%	0.82%
95	7.46%	5.20%	3.75%	2.12%
100	9.05%	6.31%	4.54%	2.65%

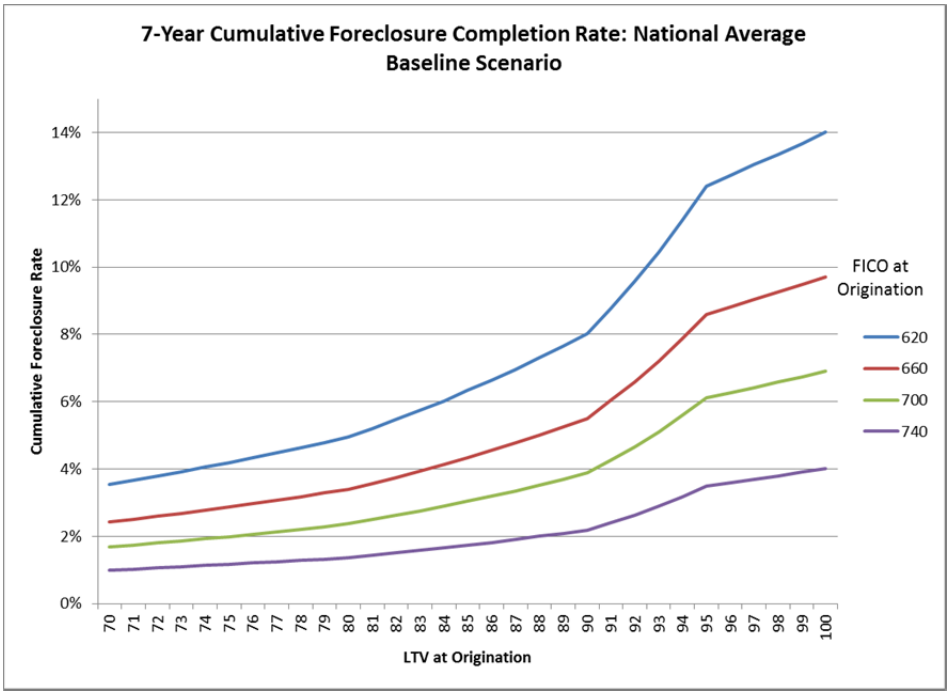
Source: FHFA

Exhibit 5: GSE Market Segment



Source: FHFA

Exhibit 6: FHA Market Segment



Source: FHFA

In Exhibits 5 and 6, separately for the GSE and FHA market segments, we plotted the LTV- foreclosure rate relationship for LTV ranging from 70 to 100. The analysis was stratified by the four FICO classes, so there are a total of four curves in each exhibit. The blue curve in Exhibit 5, for example, depicts the relationship between the original LTV and the cumulative foreclosure rate of GSE borrowers with a FICO score of 620.

All the curves in the Exhibits are with an upward slope, implying that as LTV increases, foreclosure rate would rise regardless of borrower FICO level. But the LTV-foreclosure relationship is sensitive to FICO. Furthermore, there are noticeable breaks or discontinuities in each of the four curves in the FHA market segment, representing systematical changes in the LTV- foreclosure relationship. The foreclosure rate curve starts relatively flat and then climbs upward gradually, as LTV increases from 70 to 95 percent. The rate shoots up noticeably at 90 percent LTV. Beyond 95 percent, the slope of the curves becomes relatively flat again, implying that the effect of LTV on foreclosure rate is attenuated. In comparison, the curves for the GSE borrowers are all smooth and upward sloping.

Below we summarize our additional observations on the two exhibits.

- Consistent with results from Exhibits 2, 3 and 4, the LTV-foreclosure rate relationship is nonlinear. This is true across both market segments.

- The curves in general are steeper or have a higher slope for FHA borrowers than for GSE borrowers, especially for loans in the high LTV segment. This means that the foreclosure rate is more responsive to original LTV changes in the FHA than in the GSE segment of the market. The implication is that the same level of change in original LTV requirement would have a larger impact for FHA borrowers than for GSE borrowers.[17]

- Across both market segments, the curve is steeper or has a higher slope for borrowers with a lower FICO score. This confirms that there is an interaction effect between FICO score and LTV. Put differently: the LTV-foreclosure rate relationship is sensitive to FICO. The same magnitude of LTV change would generate a larger impact on the foreclosure rate – *in terms of percentage point difference* – for borrowers with a lower FICO score than for borrowers with a higher FICO score. This disproportionate impact is observed in both the FHA and GSE market segments, as shown in Exhibit 4. For instance, if LTV was raised from 80 percent to 90 percent for borrowers with a FICO score of 620 in the GSE market segment, the foreclosure rate would increase by 4.46 percentage points. In comparison, the same change in LTV would result in an increase of foreclosure rate by only 2.23 percentage points for borrower with a FICO score of 700.

- For FHA borrowers, the curves were steepest for the segment between 90 and 95 percent LTV. A one percentage point rise in original LTV is associated with a largest increase in foreclosure

[17] Once again, this could be a reflection that combined LTV values are under-reported in the GSE data due to the incomplete second liens coverage.

rate for this LTV range than for any other LTV. This is true across the four borrower FICO score levels.

- The effect of LTV on foreclosure rate tends to rise less dramatically once original LTV goes beyond 95 percent. The curve segments between 95 and 100 LTV all have a flatter slope. While this is observed across market segments and FICO score levels, it is especially the case for the FHA borrowers.

5.1B Sensitivity to Borrower DTI Ratio

We next looked at the LTV-foreclosure rate relationship by allowing the level of front-end DTI ratio to vary (from 31 percent to 45 percent), while holding FICO score constant (at 620). The purpose of this analysis is to examine whether the relationship is sensitive to DTI. Exhibit 7 presents the ratio estimates, once again using the foreclosure rate for loans with an LTV of 80 as the baseline. Foreclosure rate changes in percentage difference format can be found in Exhibit C1 of Appendix C.

Exhibit 7: LTV-Cumulative Foreclosure Completion rate Relationship, by DTI at Origination

Moody's Baseline Economic Scenario

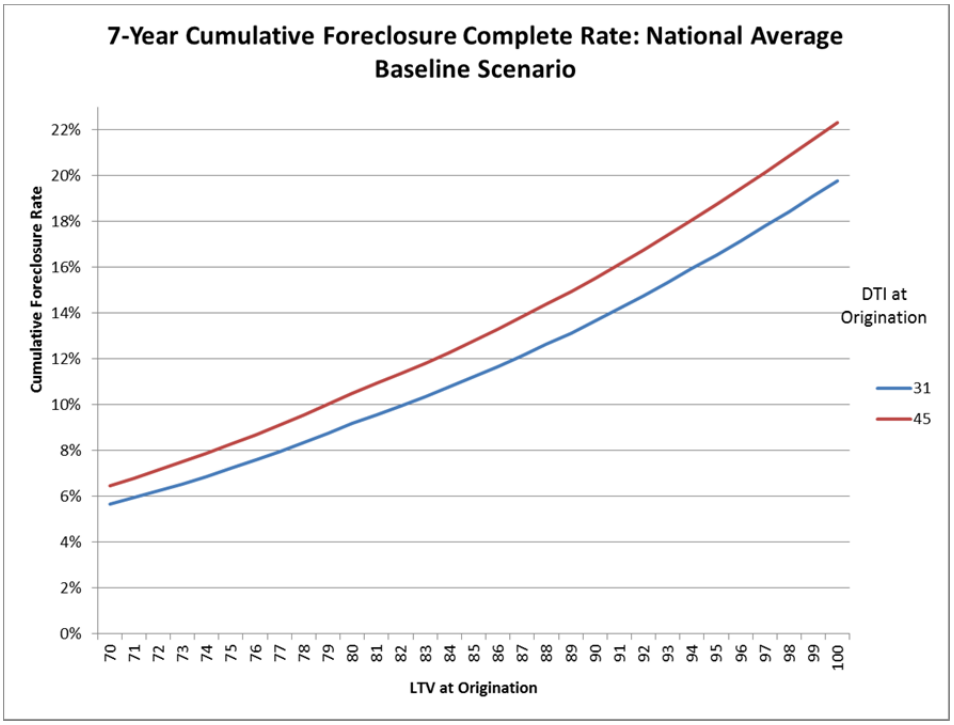
FICO at Origination = 620; Baseline LTV = 80

	GSE Market Segment	
	DTI at Origination	
LTV at Origination	31	45
80	9.20%	10.52%
Ratio Between Foreclosure Rate of LTV=80% and Foreclosure Rate of Other LTV Categories		
70	0.61	0.62
85	1.22	1.22
90	1.48	1.48
95	1.80	1.78
100	2.15	2.12

	FHA Market Segment	
	DTI at Origination	
LTV at Origination	31	45
80	4.95%	5.45%
Ratio Between Foreclosure Rate of LTV=80% and Foreclosure Rate of Other LTV Categories		
70	0.72	0.72
85	1.28	1.28
90	1.62	1.61
95	2.51	2.49
100	2.83	2.80

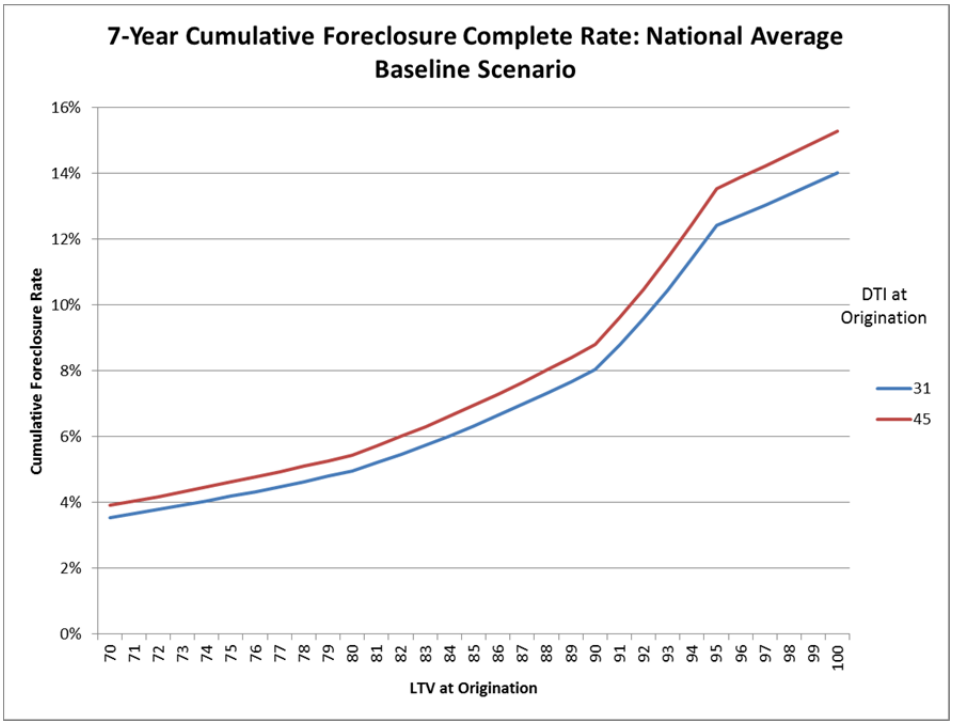
Source: FHFA

Exhibit 8: GSE Market Segment



Source: FHFA

Exhibit 9: FHA Market Segment



Source: FHFA

In Exhibits 8-9, we plotted the LTV-foreclosure rate relationship by allowing the level of LTV at origination to vary from 70 percent to 100 percent while holding FICO score constant (at 620). The two curves in each graph represent DTI at 31 percent and 45 percent respectively. Our observations are as follows.

- As expected, across all LTV levels, borrowers with a higher DTI had a higher foreclosure rate. This is true across both market segments.

- Overall, the LTV-foreclosure rate relationship has a relatively modest sensitivity to the DTI level. To be sure – there is some sensitivity, as the foreclosure completion rate is uniformly higher for the larger DTI. The dramatic effects of the FICO score impact on the LTV-foreclosure relationship are not observed here, however. This is true for both segments of the mortgage market. As Exhibit 7 shows, for each market segment, the ratio estimates are largely the same across the columns for DTI of 31 and DTI of 45.

- This is also indicated by the fact that the two curves of different DTI levels are essentially parallel in Exhibit 8 (and Exhibit 9).

5.1C Sensitivity to Loan Performance Metric

We tested the sensitivity of our analysis results to the loan performance metric we picked. Stating it differently, we ask whether our findings from the previous sections would hold if a different measure of loan performance other than foreclosure completion is used – namely, the 90-day delinquency rate. To answer this question, we replicated the simulation analyses conducted in the previous sections with the 90-day delinquency rate as the loan performance outcome.

Exhibit 10 presents the relationship between the original LTV and the cumulative 90-day delinquency rate, holding borrower FICO score and front-end DTI at 620 and 31 respectively. Exhibit 11 repeats the same analysis, separately, for borrowers with four FICO score levels: 620, 660, 700, and 740. Front-end DTI was held constant at 31. We once again used the delinquency rate of borrowers with an LTV of 80 as the baseline and computed the changes in delinquency rate in ratio (or multiple of the baseline) format.[18] Estimates based on percentage point difference are presented in Exhibit 12.

[18] Hereafter, delinquency rate means cumulative or lifetime delinquency rate, unless stated otherwise.

Exhibit 10: Relationship Between Average Cumulative 90-Day Delinquency Rate and Original LTV

Moody's Baseline Economic Scenario
FICO at Origination = 620; Front-end DTI=31
Baseline LTV = 80

	Market Segment			
	GSE		**FHA**	
LTV at Origination	**Delinquency Rate**	**Ratio to Baseline**	**Delinquency Rate**	**Ratio to Baseline**
70	29.53%	0.81	40.68%	0.95
80 (Baseline)	36.53%	1.00	42.75%	1.00
85	40.43%	1.11	43.80%	1.02
90	44.81%	1.23	44.96%	1.05
95	32.35%	1.36	51.94%	1.21
100	52.88%	1.45	53.30%	1.25

Source: FHFA

Exhibit 11: LTV-Cumulative 90-Day Delinquency Rate Relationship, by FICO Score at Origination

Moody's Baseline Economic Scenario
Front-end DTI=31; Baseline LTV = 80

	GSE Market Segment			
	FICO Score at Origination			
LTV at Origination	620	660	700	740
80	36.53%	22.36%	14.29%	7.89%
Ratio Between Delinquency Rate of LTV=80% and Delinquency Rate of Other LTV Categories				
70	0.81	0.80	0.79	0.79
85	1.11	1.12	1.13	1.13
90	1.23	1.26	1.28	1.29
95	1.36	1.44	1.48	1.53
100	1.45	1.56	1.62	1.74

	FHA Market Segment			
	FICO Score at Origination			
LTV at Origination	620	660	700	740
80	42.75%	27.87%	16.88%	10.39%
Ratio Between Delinquency Rate of LTV=80% and Delinquency Rate of Other LTV Categories				
70	0.95	0.94	0.94	0.95
85	1.02	1.03	1.03	1.03
90	1.05	1.06	1.06	1.06
95	1.21	1.25	1.28	1.29
100	1.25	1.29	1.32	1.30

Source: FHFA

Exhibit 12: LTV-Cumulative 90-Day Delinquency Rate Relationship, by FICO Score at Origination
Percentage Point Difference Estimates
Moody's Baseline Economic Scenario
Front-end DTI=31; Baseline LTV = 80

	GSE Market Segment			
	FICO Score at Origination			
LTV at Origination	620	660	700	740
80	36.53%	22.36%	14.29%	7.89%
Percentage Point Difference Between Delinquency Rate of LTV=80% and Delinquency Rate of Other LTV Categories				
70	-7.00%	-4.54%	-3.04%	-1.63%
85	3.90%	2.65%	1.81%	0.99%
90	8.28%	5.86%	4.02%	2.32%
95	13.19%	9.77%	6.79%	4.17%
100	16.35%	12.63%	8.83%	5.84%

	FHA Market Segment			
	FICO Score at Origination			
LTV at Origination	620	660	700	740
80	42.75%	27.87%	16.88%	10.39%
Percentage Point Difference Between Delinquency Rate of LTV=80% and Delinquency Rate of Other LTV Categories				
70	-2.08%	-1.58%	-1.05%	-0.57%
85	1.05%	0.78%	0.53%	0.29%
90	2.21%	1.60%	1.08%	0.61%
95	9.19%	7.02%	4.79%	3.04%
100	10.54%	7.96%	5.45%	3.53%

Source: FHFA

- Overall, we found that, the LTV-delinquency rate relationship is very much like the LTV-foreclosure rate relationship. As the original LTV rises, the lifetime delinquency rate increases monotonically. This is true for both segments of the market and across FICO levels.

- Comparing the ratio estimates presented in Exhibits 3 and 10, it is obvious that adjusting original LTV would generate a larger impact on foreclosure rate than on delinquency rate, regardless of market segment. For example, Exhibit 3 indicates that if LTV is increased from 80 to 90 percent for a GSE borrower with FICO score of 660, the foreclosure rate would be 1.48 times the baseline level. The corresponding estimate for delinquency rate would be 1.26 times the baseline level, as shown in Exhibit 10. This comparison is more dramatic for FHA loans. If LTV is raised from 80 to 95 percent for a borrower with FICO score of 660, the foreclosure rate would

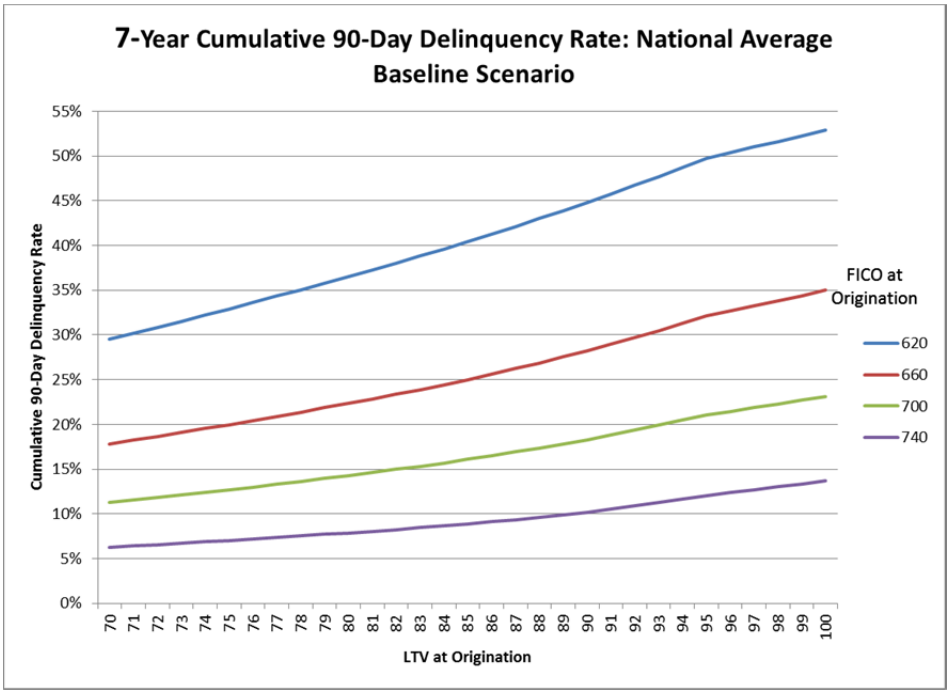
be more than double (2.53 times) the baseline level. The corresponding estimate for delinquency rate would be 1.25 times the baseline level.

- Exhibit 11 indicates that, when expressed in ratio (or multiple) format, the LTV-delinquency rate relationship varies somewhat across borrower FICO levels. As the LTV rises, the increase in delinquency rate (as ratio to baseline rate) appears to be slightly larger for borrowers with higher FICO.

- This difference in LTV-delinquency relationship across the four FICO classes becomes more obvious when we look at the estimates in percentage point difference format presented in Exhibit 12. For example, if we increased the original LTV from 80 percent to 90 percent for borrowers with a FICO score of 620 in the GSE market segment, the delinquency rate would increase by 8.28 percentage points. In comparison, the same change in LTV would generate an increase of delinquency rate by only 2.32 percentage points for borrower with a FICO score of 740.

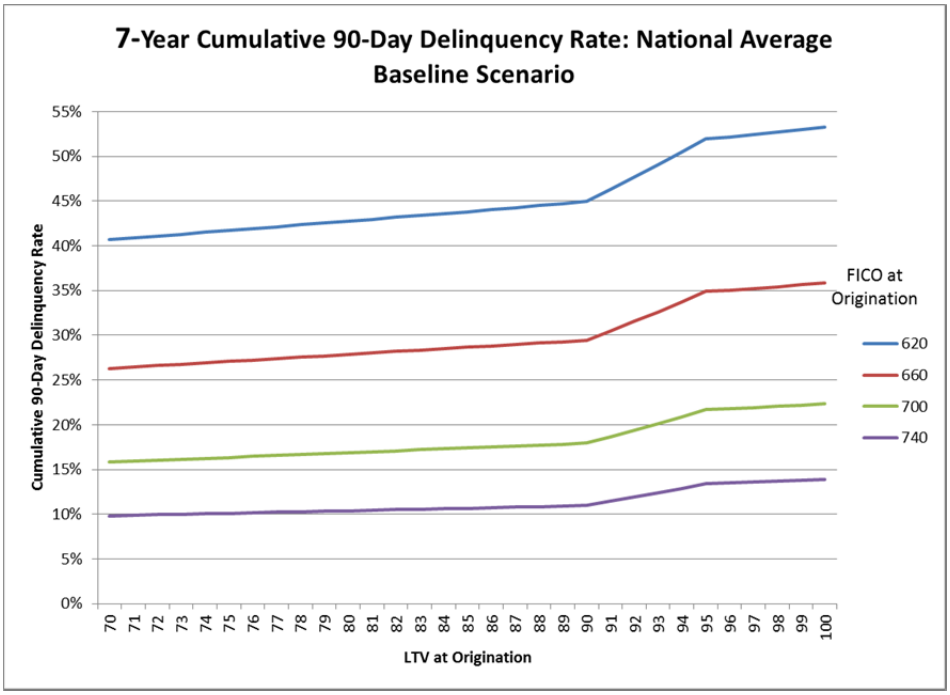
In Exhibits 13 and 14, separately for the GSE and FHA market segments, we plotted the LTV-delinquency rate relationship for original LTV ranging from 70 to 100. Once again, the analysis was stratified by the four FICO classes, so there are a total of four curves in each exhibit. Consistent with the findings for the foreclosure rate, we found that all curves have an upward slope. The curves tend to have a flatter slope for the delinquency outcome than for the foreclosure outcome. In other words, the same magnitude of original LTV changes is associated with a smaller impact on delinquency outcomes than on the foreclosure outcome. Comparing between market segments, the curves for the FHA borrowers have a relatively flatter slope.

Exhibit 13: GSE Market Segment



Source: FHFA

Exhibit 14: FHA Market Segment



Source: FHFA

Next, in Exhibit 15, to explore whether the LTV-delinquency rate relationship is sensitive to borrower DTI, we held FICO score stable (620) and examined the effect of LTV on delinquency rate for borrowers with different DTI levels (31 percent and 45 percent). Once again, the effect was shown in terms of ratio estimate. Results for percentage point difference format are presented in Exhibit C2 of Appendix C.

Just as we have seen in the LTV-foreclosure relationship before, the LTV- delinquency rate relationship is sensitive to borrower DTI levels, but the impact is not particularly dramatic.

Exhibit15: Relationship Between Cumulative 90-Day Delinquency Rate and DTI at Origination

Moody's Baseline Economic Scenario

FICO at Origination = 620; Baseline LTV = 80

	GSE Market Segment	
	DTI Ratio at Origination	
LTV at Origination	31	45
80	36.53%	45.18%
Ratio Between Delinquency Rate of LTV=80% and Delinquency Rate of Other LTV Categories		
70	0.81	0.82
85	1.11	1.10
90	1.23	1.20
95	1.36	1.32
100	1.45	1.39

	FHA Market Segment	
	DTI Ratio at Origination	
LTV at Origination	31	45
80	42.75%	48.47%
Ratio Between Delinquency Rate of LTV=80% and Delinquency Rate of Other LTV Categories		
70	0.95	0.95
85	1.02	1.02
90	1.05	1.05
95	1.21	1.20
100	1.25	1.23

Source: FHFA

6. Conclusion

In this study, using hazard rate models and simulations, we examined the relationship between down payment requirement (in terms of LTV) and loan performance outcomes. The metric of loan performance included both foreclosure completion rate and seriously delinquency rate. Our estimation sample included large samples of longitudinal loan records covering both the GSE and FHA segment of the mortgage market. The stylized results allow us to quantify the marginal or incremental effect of adjusting LTV at loan origination on loan performance. The sensitivity of our results to other underwriting variables – namely, borrower FICO score and DTI ratio – has been examined.

To explore the sensitivity of our results to the macro-economic variables used in the simulation, it should be noted that we have replicated the analyses using Moody's more pessimistic "protracted slump" scenario forecast of house price appreciation and unemployment rates. We found that our overall results do not change significantly when the alternative scenario is used.

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Appendix A

Exhibit A1: Multinomial Logit Model Coefficient Estimates of Competing Hazard Models (Standard Errors under Point Estimates): GSE Market Segment

	Model 1		Model 2	
	Prepayment	90-Day Delinquency	Prepayment	Foreclosure Completion
Mortgage Age (Seasoning) Splines				
Less than 6 months	0.192***	0.404***	0.192***	0.245***
	(0.003)	(0.009)	(0.003)	(0.025)
6 to than less 12 Months	0.069***	0.033***	0.069***	0.137***
	(0.001)	(0.004)	(0.001)	(0.010)
12 to less than 24 months	0.006***	0.043***	0.005***	0.068***
	(0.001)	(0.002)	(0.001)	(0.003)
24 to less than 36 months	-0.015***	-0.001	-0.015***	0.038***
	(0.001)	(0.002)	(0.001)	(0.002)
36 to less than 48 months	-0.002***	-0.001	-0.003***	0.010***
	(0.001)	(0.002)	(0.001)	(0.002)
48 to less than 60 months	-0.012***	0.012***	-0.012***	0.015***
	(0.001)	(0.002)	(0.001)	(0.002)
60 to less than 72 months	-0.016***	0.013***	-0.016***	0.013***
	(0.001)	(0.002)	(0.001)	(0.002)
72+ months	-0.019***	0.010***	-0.019***	0.009***
	(0.000)	(0.000)	(0.000)	(0.001)
Seasonality				
February	0.125***	-0.173***	0.127***	0.061**
	(0.006)	(0.019)	(0.006)	(0.027)
March	0.214***	-0.265***	0.220***	0.095***
	(0.006)	(0.019)	(0.006)	(0.027)
April	0.193***	-0.253***	0.190***	0.141***
	(0.006)	(0.019)	(0.006)	(0.027)
May	0.141***	-0.153***	0.144***	0.136***
	(0.006)	(0.019)	(0.006)	(0.027)
June	0.186***	-0.091***	0.192***	0.234***
	(0.006)	(0.019)	(0.006)	(0.026)
July	0.273***	-0.120***	0.269***	0.168***
	(0.006)	(0.019)	(0.006)	(0.027)
August	0.286***	-0.069***	0.285***	0.259***
	(0.006)	(0.018)	(0.006)	(0.026)
September	0.160***	-0.007	0.163***	0.173***
	(0.006)	(0.018)	(0.006)	(0.027)
October	0.221***	0.042**	0.218***	0.152***
	(0.006)	(0.018)	(0.006)	(0.026)
November	0.151***	0.059***	0.153***	0.112***
	(0.006)	(0.018)	(0.006)	(0.027)
December	0.176***	0.289***	0.185***	0.000

	Model 1		Model 2	
	Prepayment	90-Day Delinquency	Prepayment	Foreclosure Completion
	(0.006)	(0.017)	(0.006)	(0.027)
Cohort Year				
Cohort Year 1996	0.004	0.060	-0.007	0.120**
	(0.009)	(0.038)	(0.009)	(0.058)
Cohort Year 1997	-0.011	-0.013	-0.023***	0.133**
	(0.009)	(0.039)	(0.009)	(0.058)
Cohort Year 1998	0.064***	-0.188***	0.046***	-0.163***
	(0.009)	(0.037)	(0.009)	(0.057)
Cohort Year 1999	-0.009	0.048	-0.028***	0.182***
	(0.009)	(0.037)	(0.009)	(0.056)
Cohort Year 2000	0.093***	0.481***	0.071***	0.734***
	(0.009)	(0.038)	(0.009)	(0.057)
Cohort Year 2001	-0.049***	0.196***	-0.065***	0.399***
	(0.009)	(0.037)	(0.009)	(0.055)
Cohort Year 2002	-0.052***	0.219***	-0.068***	0.386***
	(0.009)	(0.036)	(0.009)	(0.054)
Cohort Year 2003	-0.131***	0.146***	-0.148***	0.030
	(0.009)	(0.035)	(0.009)	(0.053)
Cohort Year 2004	-0.200***	0.205***	-0.211***	-0.053
	(0.009)	(0.035)	(0.009)	(0.053)
Cohort Year 2005	-0.375***	0.349***	-0.381***	0.101*
	(0.010)	(0.034)	(0.009)	(0.052)
Cohort Year 2006	-0.543***	0.630***	-0.553***	0.364***
	(0.010)	(0.034)	(0.010)	(0.052)
Cohort Year 2007	-0.659***	0.771***	-0.674***	0.498***
	(0.010)	(0.034)	(0.010)	(0.053)
Cohort Year 2008	-0.699***	0.757***	-0.713***	0.562***
	(0.011)	(0.035)	(0.010)	(0.054)
Original LTV Splines				
LTV less than 70	-0.017	0.188	0.078***	-1.994***
	(0.024)	(0.157)	(0.024)	(0.269)
LTV 70 to less than 80	0.426***	1.191***	0.479***	1.461***
	(0.047)	(0.235)	(0.046)	(0.370)
LTV 80 to less than 90	0.320***	1.092***	0.404***	0.520**
	(0.042)	(0.146)	(0.042)	(0.209)
LTV 90 to less than 95	1.922***	1.380***	1.949***	0.711*
	(0.087)	(0.264)	(0.086)	(0.374)
LTV 95+	-2.252***	-0.211	-2.217***	0.283
	(0.125)	(0.222)	(0.123)	(0.303)
Credit Score Splines				
FICO less than 620	3.979***	-6.638***	3.919***	-5.478***
	(0.203)	(0.229)	(0.188)	(0.315)
FICO 620 to less than 660	1.586***	-12.734***	1.395***	-7.074***

	Model 1		Model 2	
	Prepayment	90-Day Delinquency	Prepayment	Foreclosure Completion
	(0.300)	(0.638)	(0.292)	(0.948)
FICO 660 to less than 700	0.567***	-12.496***	0.340	-7.612***
	(0.210)	(0.632)	(0.207)	(0.917)
FICO 700+	0.052	-12.292***	0.168***	-7.467***
	(0.050)	(0.239)	(0.050)	(0.321)
Front-End Debt-to-Income (DTI) Splines				
DTI less than 25	0.436***	2.320***	0.373***	1.451***
	(0.032)	(0.121)	(0.031)	(0.168)
DTI 25 to less than 31	-0.324***	3.521***	-0.393***	3.193***
	(0.086)	(0.268)	(0.085)	(0.378)
DTI 31 to less than 35	-0.651***	4.219***	-0.840***	2.037***
	(0.159)	(0.409)	(0.157)	(0.580)
DTI 35+	-0.300***	1.146***	-0.311***	0.532***
	(0.049)	(0.099)	(0.048)	(0.148)
Back-End Debt-to-Income (DTI) Splines				
DTI less than 30	0.046	-0.628***	0.084**	-0.755***
	(0.037)	(0.163)	(0.037)	(0.224)
DTI 30 to less than 35	0.064	1.737***	0.118	1.834***
	(0.096)	(0.347)	(0.095)	(0.488)
DTI 35 to less than 42	-0.174**	0.158	-0.193***	0.126
	(0.069)	(0.210)	(0.069)	(0.298)
DTI 42+	-0.077***	0.041	-0.100***	-0.185*
	(0.027)	(0.068)	(0.027)	(0.099)
FICO Score and MTMLTV Interaction				
(FICO less than 620)*(MTMLTV less than 80)	-0.874***	1.748***	-1.010***	4.583***
	(0.026)	(0.073)	(0.025)	(0.129)
(FICO less than 620)*(MTMLTV 80 to less than 100)	-4.251***	3.027***	-5.087***	3.752***
	(0.123)	(0.138)	(0.116)	(0.196)
(FICO less than 620)*(MTMLTV 100 to less than 125)	-3.197***	-0.626***	-4.289***	0.152
	(0.325)	(0.172)	(0.275)	(0.189)
(FICO less than 620)*(MTMLTV 125+)	-1.039*	0.680***	-0.243	0.805***
	(0.530)	(0.167)	(0.292)	(0.115)
(FICO 620 to less than 660)*(MTMLTV less than 80)	-0.844***	1.786***	-0.972***	4.465***
	(0.019)	(0.069)	(0.019)	(0.125)
(FICO 620 to less than 660)*(MTMLTV 80 to less than 100)	-4.377***	1.968***	-4.747***	3.506***
	(0.082)	(0.135)	(0.080)	(0.201)
(FICO 620 to less than 660)*(MTMLTV 100 to less than 125)	-2.663***	1.252***	-3.429***	1.773***
	(0.191)	(0.140)	(0.176)	(0.175)
(FICO 620 to less than 660)*(MTMLTV 125+)	-1.413***	0.772***	-1.248***	1.059***
	(0.311)	(0.116)	(0.233)	(0.097)
(FICO 660 to less than 700)*(MTMLTV less than 80)	-0.755***	1.671***	-0.860***	4.260***
	(0.016)	(0.068)	(0.015)	(0.126)
(FICO 660 to less than 700)*(MTMLTV 80	-4.109***	2.715***	-4.326***	4.424***

	Model 1		Model 2	
	Prepayment	90-Day Delinquency	Prepayment	Foreclosure Completion
to less than 100)	(0.063)	(0.140)	(0.062)	(0.207)
(FICO 660 to less than 700)*(MTMLTV 100 to less than 125)	-1.518***	2.076***	-2.042***	2.332***
	(0.133)	(0.136)	(0.127)	(0.175)
(FICO 660 to less than 700)*(MTMLTV 125+)	-2.028***	0.980***	-1.944***	1.340***
	(0.223)	(0.100)	(0.187)	(0.094)
(FICO 700+)*(MTMLTV less than 80)	-0.660***	1.465***	-0.761***	4.001***
	(0.015)	(0.071)	(0.014)	(0.132)
(FICO 700+)*(MTMLTV 80 to less than 100)	-3.131***	4.284***	-3.195***	5.352***
	(0.041)	(0.132)	(0.040)	(0.186)
(FICO 700+)*(MTMLTV 100 to less than 125)	-1.298***	3.078***	-1.598***	3.431***
	(0.070)	(0.111)	(0.069)	(0.142)
(FICO 700+)*(MTMLTV 125+)	-1.452***	0.953***	-1.606***	1.442***
	(0.103)	(0.073)	(0.097)	(0.075)
Original UPB Splines (in 1,000s)				
UPB less than $100	0.012***	-0.000	0.012***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
UPB $100 to less than $200	0.005***	0.001***	0.005***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
UPB $200 to less than $300	0.002***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
UPB $300+	0.001***	0.003***	0.001***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Mortgage Rate Spread at Origination (SATO) Splines				
SATO less than 0.17	0.821***	0.637***	0.803***	0.533***
	(0.005)	(0.021)	(0.005)	(0.030)
SATO 0.17+	0.352***	0.424***	0.310***	0.462***
	(0.004)	(0.007)	(0.004)	(0.009)
Yield Curve Spread				
10-yr Treasury yield - 2-yr Treasury yield	-0.231***		-0.227***	
	(0.002)		(0.002)	
Refinance-Burnout Interaction				
(Refi less than 1.15)*(burnout less than 0.3)	6.704***		6.633***	
	(0.028)		(0.028)	
(Refi 1.15 to less than 1.25)*(burnout less than 0.3)	6.696***		6.624***	
	(0.027)		(0.027)	
(Refi 1.25+)*(burnout less than 0.3)	6.658***		6.589***	
	(0.027)		(0.026)	
(Refi less than 1.15)*(burnout 0.3 to less than 0.8)	9.115***		9.084***	
	(0.146)		(0.146)	
(Refi 1.15 to less than 1.25)*(burnout 0.3 to less than 0.8)	6.455***		6.393***	
	(0.099)		(0.099)	

	Model 1		Model 2	
	Prepayment	90-Day Delinquency	Prepayment	Foreclosure Completion
(Refi 1.25+)*(burnout 0.3 to less than 0.8)	3.961***		3.815***	
	(0.068)		(0.067)	
(Refi less than 1.15)*(burnout 0.8+)	-27.506***		-26.592***	
	(5.425)		(5.400)	
(Refi 1.15 to less than 1.25)*(burnout 0.8+)	1.958***		1.994***	
	(0.286)		(0.285)	
(Refi 1.25+)*(burnout 0.8+)	1.842***		1.722***	
	(0.016)		(0.015)	
Metro/Non-Metro				
Located in MSA	0.017***	0.016	0.018***	-0.028*
	(0.004)	(0.012)	(0.004)	(0.016)
State Law Indicator				
Non-judicial and anti-deficiency	0.040***	-0.015	0.039***	0.086***
	(0.004)	(0.013)	(0.004)	(0.018)
Judicial and no anti-deficiency	-0.009***	0.099***	-0.013***	-0.151***
	(0.003)	(0.010)	(0.003)	(0.014)
Judicial and anti-deficiency	0.161***	0.238***	0.155***	-0.111***
	(0.007)	(0.024)	(0.007)	(0.036)
Census Division				
New England	0.164***	-0.082***	0.159***	-0.298***
	(0.006)	(0.024)	(0.006)	(0.038)
Mid-Atlantic	-0.098***	-0.140***	-0.103***	-0.300***
	(0.005)	(0.015)	(0.005)	(0.025)
Northeast Central	0.411***	-0.110***	0.404***	0.141***
	(0.004)	(0.012)	(0.004)	(0.016)
Northwest Central	0.251***	-0.002	0.249***	0.094***
	(0.005)	(0.018)	(0.005)	(0.024)
Southeast Central	0.147***	-0.067***	0.145***	0.108***
	(0.006)	(0.019)	(0.006)	(0.026)
Southwest Central	-0.209***	-0.147***	-0.206***	-0.152***
	(0.006)	(0.018)	(0.006)	(0.025)
Mountain	0.173***	0.116***	0.176***	0.172***
	(0.005)	(0.015)	(0.005)	(0.021)
Pacific	0.147***	-0.123***	0.147***	-0.082***
	(0.006)	(0.019)	(0.006)	(0.026)
State Unemployment Rate Splines				
Unemployment less than 6%	-0.037***	0.177***	-0.035***	0.131***
	(0.002)	(0.007)	(0.002)	(0.011)
Unemployment less 6%+	-0.124***	0.047***	-0.122***	-0.025***
	(0.001)	(0.003)	(0.001)	(0.004)
Second Lien Indicator				

	Model 1		Model 2	
	Prepayment	90-Day Delinquency	Prepayment	Foreclosure Completion
Yes	-0.091***	-0.396***	-0.080***	-0.558***
	(0.006)	(0.015)	(0.006)	(0.022)
Number of Housing Units				
More than one	-0.394***	0.046	-0.383***	0.318***
	(0.012)	(0.034)	(0.011)	(0.049)
Structure Type				
Condominium	-0.083***	-0.012	-0.077***	0.174***
	(0.004)	(0.013)	(0.004)	(0.017)
Constant	-16.424***	-8.038***	-16.217***	-10.014***
	(0.131)	(0.189)	(0.122)	(0.298)
Log likelihood	-3,933,069.3		-3,806,355.3	
Likelihood ratio Chi-square	672,208.0		580,353.9	
Chi-square d.o.f.	186		186	
Number of loan-month records	43,253,692		44,809,900	

Notes: Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: FHFA

Exhibit A2: Multinomial Logit Model Coefficient Estimates of Competing Hazard Models (Standard Errors under Point Estimates): FHA Market Segment

	Model 1		Model 2	
	Prepayment	90-Day Delinquency	Prepayment	Foreclosure Completion
Mortgage Age (Seasoning) Splines				
Less than 6 months	0.144***	0.229***	0.139***	0.595***
	(0.002)	(0.002)	(0.002)	(0.027)
6 to than less 12 Months	-0.048***	-0.001	-0.054***	0.159***
	(0.002)	(0.002)	(0.002)	(0.006)
12 to less than 24 months	0.001	0.003	0.002	0.049***
	(0.003)	(0.003)	(0.003)	(0.006)
24 to less than 36 months	-0.030***	-0.005	-0.040***	0.011**
	(0.003)	(0.003)	(0.003)	(0.005)
36 to less than 48 months	-0.032***	-0.010***	-0.025***	0.034***
	(0.002)	(0.002)	(0.002)	(0.003)
48+ months	-0.012***	-0.000	-0.015***	0.008***
	(0.000)	(0.000)	(0.000)	(0.001)
Seasonality				
February	-0.063***	-0.137***	-0.068***	0.047*
	(0.014)	(0.015)	(0.014)	(0.027)
March	-0.086***	-0.335***	-0.090***	0.379***
	(0.014)	(0.016)	(0.014)	(0.025)
April	-0.083***	-0.526***	-0.088***	0.193***
	(0.014)	(0.017)	(0.014)	(0.027)
May	-0.066***	-0.420***	-0.075***	0.185***
	(0.014)	(0.017)	(0.014)	(0.027)
June	-0.012	-0.330***	-0.019	0.303***
	(0.014)	(0.016)	(0.014)	(0.026)
July	0.010	-0.301***	0.009	0.241***
	(0.014)	(0.016)	(0.014)	(0.026)
August	0.059***	-0.204***	0.074***	0.299***
	(0.014)	(0.016)	(0.013)	(0.026)
September	0.010	-0.135***	0.041***	0.213***
	(0.014)	(0.015)	(0.014)	(0.026)
October	0.091***	-0.080***	0.135***	0.153***
	(0.013)	(0.015)	(0.013)	(0.026)
November	-0.040***	-0.038**	0.012	0.040
	(0.014)	(0.015)	(0.013)	(0.027)
December	0.260***	0.247***	0.065***	0.083***
	(0.012)	(0.014)	(0.013)	(0.026)
Cohort Year				
Cohort Year 2005	0.030***	0.021	0.022**	-0.077***
	(0.011)	(0.013)	(0.011)	(0.019)
Cohort Year 2006	-0.133***	0.199***	-0.108***	0.032

	Model 1		Model 2	
	Prepayment	90-Day Delinquency	Prepayment	Foreclosure Completion
	(0.012)	(0.014)	(0.012)	(0.021)
Cohort Year 2007	-0.256***	0.339***	-0.240***	0.159***
	(0.015)	(0.016)	(0.015)	(0.023)
Cohort Year 2008	-0.287***	0.206***	-0.249***	0.032
	(0.017)	(0.016)	(0.016)	(0.024)
Original LTV Splines				
LTV less than 80	3.612***	-0.291	3.601***	-1.724***
	(0.186)	(0.260)	(0.181)	(0.608)
LTV 80 to less than 90	2.867***	-0.431	3.227***	-0.105
	(0.278)	(0.344)	(0.276)	(0.671)
LTV 90 to less than 95	1.612***	2.813***	1.363***	4.090***
	(0.352)	(0.453)	(0.353)	(0.791)
LTV 99+	4.274***	-0.350	4.582***	-2.045***
	(0.360)	(0.436)	(0.363)	(0.683)
Credit Score Splines				
FICO less than 620	1.335***	-3.750***	2.796***	-2.477***
	(0.180)	(0.095)	(0.186)	(0.164)
FICO 620 to less than 660	4.881***	-12.919***	6.655***	-7.000***
	(0.480)	(0.561)	(0.478)	(0.888)
FICO 660 to less than 700	2.662***	-14.023***	4.253***	-8.220***
	(0.484)	(0.786)	(0.485)	(1.182)
FICO 700+	2.023***	-10.215***	2.530***	-7.381***
	(0.156)	(0.438)	(0.158)	(0.624)
Front-End Debt-to-Income (DTI) Splines				
DTI less than 25	-0.489***	4.141***	-0.964***	4.618***
	(0.085)	(0.115)	(0.084)	(0.183)
DTI 25 to less than 31	-0.480***	3.118***	-1.080***	2.125***
	(0.175)	(0.209)	(0.175)	(0.322)
DTI 31 to less than 35	-0.580*	2.461***	-0.996***	1.278**
	(0.309)	(0.353)	(0.310)	(0.550)
DTI 35+	-0.341*	0.743***	-0.502***	0.326
	(0.175)	(0.187)	(0.176)	(0.308)
Back-End Debt-to-Income (DTI) Splines				
DTI less than 30	0.085	-0.488**	0.293*	-0.887**
	(0.167)	(0.223)	(0.167)	(0.361)
DTI 30 to less than 35	0.542**	0.478	0.559**	0.941*
	(0.253)	(0.317)	(0.253)	(0.498)
DTI 35 to less than 42	-0.088	0.847***	-0.213	0.297
	(0.147)	(0.175)	(0.147)	(0.271)
DTI 42+	-0.285***	-0.055	-0.223***	0.235
	(0.081)	(0.100)	(0.082)	(0.155)

	Model 1		Model 2	
	Prepayment	90-Day Delinquency	Prepayment	Foreclosure Completion
FICO Score and MTMLTV Interaction				
(FICO less than 620)*(MTMLTV less than 80)	-5.145***	1.092***	-5.368***	6.434***
	(0.133)	(0.227)	(0.133)	(0.463)
(FICO less than 620)*(MTMLTV 80 to less than 100)	-4.095***	2.151***	-4.947***	5.104***
	(0.105)	(0.106)	(0.103)	(0.166)
(FICO less than 620)*(MTMLTV 100 to less than 125)	-0.830***	0.123	-1.976***	1.526***
	(0.117)	(0.084)	(0.117)	(0.113)
(FICO less than 620)*(MTMLTV 125+)	-0.821***	0.445***	-1.076***	1.064***
	(0.172)	(0.087)	(0.162)	(0.082)
(FICO 620 to less than 660)*(MTMLTV less than 80)	-5.154***	0.887***	-5.409***	6.145***
	(0.132)	(0.228)	(0.131)	(0.464)
(FICO 620 to less than 660)*(MTMLTV 80 to less than 100)	-3.916***	1.949***	-4.486***	5.576***
	(0.107)	(0.140)	(0.107)	(0.227)
(FICO 620 to less than 660)*(MTMLTV 100 to less than 125)	-0.341***	1.416***	-0.986***	2.257***
	(0.111)	(0.104)	(0.112)	(0.149)
(FICO 620 to less than 660)*(MTMLTV 125+)	-1.112***	0.680***	-1.509***	1.084***
	(0.163)	(0.094)	(0.162)	(0.097)
(FICO 660 to less than 700)*(MTMLTV less than 80)	-5.202***	0.873***	-5.492***	6.036***
	(0.132)	(0.231)	(0.132)	(0.467)
(FICO 660 to less than 700)*(MTMLTV 80 to less than 100)	-3.546***	1.836***	-3.995***	5.708***
	(0.111)	(0.197)	(0.112)	(0.309)
(FICO 660 to less than 700)*(MTMLTV 100 to less than 125)	-0.349***	2.427***	-0.593***	3.192***
	(0.110)	(0.136)	(0.111)	(0.191)
(FICO 660 to less than 700)*(MTMLTV 125+)	-1.061***	0.767***	-1.500***	1.135***
	(0.168)	(0.125)	(0.167)	(0.122)
(FICO 700+)*(MTMLTV less than 80)	-5.216***	0.716***	-5.563***	5.652***
	(0.133)	(0.236)	(0.133)	(0.475)
(FICO 700+)*(MTMLTV 80 to less than 100)	-3.128***	2.219***	-3.405***	7.167***
	(0.097)	(0.256)	(0.099)	(0.395)
(FICO 700+)*(MTMLTV 100 to less than 125)	-0.548***	3.429***	-0.475***	3.832***
	(0.091)	(0.161)	(0.091)	(0.221)
(FICO 700+)*(MTMLTV 125+)	-0.921***	1.180***	-1.269***	1.288***
	(0.136)	(0.132)	(0.137)	(0.137)
Original UPB Splines (in 1,000s)				
UPB less than $100	0.018***	0.000	0.016***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
UPB $100 to less than $200	0.008***	0.001***	0.008***	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
UPB $200 to less than $300	0.005***	0.004***	0.004***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)
UPB $300+	0.001***	0.001***	0.001***	0.001*
	(0.000)	(0.000)	(0.000)	(0.000)
Mortgage Rate Spread at Origination (SATO) Splines				
SATO less than 0.17	0.801***	0.198***	0.760***	0.159***

	Model 1		Model 2	
	Prepayment	90-Day Delinquency	Prepayment	Foreclosure Completion
	(0.010)	(0.012)	(0.010)	(0.019)
SATO 0.17+	0.507***	0.409***	0.404***	0.351***
	(0.011)	(0.012)	(0.011)	(0.019)
Yield Curve Spread				
10-yr Treasury yield - 2-yr Treasury yield	-0.005		0.011	
	(0.008)		(0.008)	
Refinance-Burnout Interaction				
(Refi less than 1.15)*(burnout less than 0.3)	5.768***		5.680***	
	(0.089)		(0.087)	
(Refi 1.15 to less than 1.25)*(burnout less than 0.3)	5.457***		5.353***	
	(0.087)		(0.085)	
(Refi 1.25+)*(burnout less than 0.3)	5.501***		5.316***	
	(0.089)		(0.087)	
(Refi less than 1.15)*(burnout 0.3 to less than 0.8)	8.700***		8.587***	
	(0.273)		(0.271)	
(Refi 1.15 to less than 1.25)*(burnout 0.3 to less than 0.8)	10.360***		10.469***	
	(0.267)		(0.263)	
(Refi 1.25+)*(burnout 0.3 to less than 0.8)	2.463***		3.757***	
	(0.263)		(0.263)	
(Refi less than 1.15)*(burnout 0.8+)	4.841		5.067	
	(6.403)		(6.370)	
(Refi 1.15 to less than 1.25)*(burnout 0.8+)	7.304***		7.303***	
	(0.423)		(0.419)	
(Refi 1.25+)*(burnout 0.8+)	2.886***		1.981***	
	(0.038)		(0.038)	
Source of Down Payment Assistance				
Relative of Borrower	0.028***	-0.037***	0.034***	-0.080***
	(0.008)	(0.010)	(0.008)	(0.017)
Non-Profit Organization	-0.116***	0.272***	-0.154***	0.468***
	(0.010)	(0.011)	(0.010)	(0.015)
Government	-0.112***	0.110***	-0.117***	0.135***
	(0.016)	(0.016)	(0.016)	(0.025)
Metro/Non-Metro				
Located in MSA	0.084***	-0.001	0.085***	0.052**
	(0.014)	(0.015)	(0.013)	(0.024)
State Law Indicator				
Non-judicial and anti-deficiency	-0.006	-0.011	-0.009	0.124***
	(0.010)	(0.012)	(0.010)	(0.018)
Judicial and no anti-deficiency	-0.105***	0.020**	-0.121***	-0.197***
	(0.008)	(0.009)	(0.008)	(0.015)
Judicial and anti-deficiency	0.153***	0.173***	0.166***	-0.319***

	Model 1		Model 2	
	Prepayment	90-Day Delinquency	Prepayment	Foreclosure Completion
	(0.017)	(0.022)	(0.017)	(0.039)
Census Division				
New England	0.217***	-0.100***	0.241***	-0.064
	(0.016)	(0.024)	(0.016)	(0.041)
Mid-Atlantic	-0.009	-0.161***	0.001	-0.550***
	(0.011)	(0.015)	(0.012)	(0.032)
Northeast Central	0.472***	-0.061***	0.482***	0.321***
	(0.010)	(0.011)	(0.010)	(0.017)
Northwest Central	0.457***	0.018	0.473***	0.311***
	(0.012)	(0.016)	(0.012)	(0.025)
Southeast Central	0.170***	-0.037***	0.167***	0.435***
	(0.012)	(0.014)	(0.012)	(0.023)
Southwest Central	-0.348***	-0.066***	-0.339***	0.349***
	(0.013)	(0.015)	(0.013)	(0.025)
Mountain	0.392***	0.064***	0.411***	0.482***
	(0.010)	(0.014)	(0.010)	(0.021)
Pacific	0.161***	-0.132***	0.204***	0.221***
	(0.014)	(0.018)	(0.014)	(0.028)
State Unemployment Rate Splines				
Unemployment less than 6%	-0.047***	0.156***	-0.038***	-0.044***
	(0.006)	(0.007)	(0.006)	(0.013)
Unemployment less 6%+	-0.010***	0.050***	-0.013***	-0.045***
	(0.002)	(0.002)	(0.002)	(0.004)
Number of Housing Units				
More than one	-0.356***	-0.014	-0.334***	-0.003
	(0.022)	(0.028)	(0.022)	(0.048)
Structure Type				
Condominium	0.007	-0.068***	0.027**	0.014
	(0.011)	(0.015)	(0.011)	(0.023)
Constant	-13.680***	-7.938***	-14.022***	-18.880***
	(0.187)	(0.181)	(0.185)	(0.602)
Log likelihood	-1,311,064.4		-1,049,035.3	
Likelihood ratio Chi-square	194,216.08		140,472.14	
Chi-square d.o.f.	166		166	
Number of loan-month records	15,363,028		17,800,056	

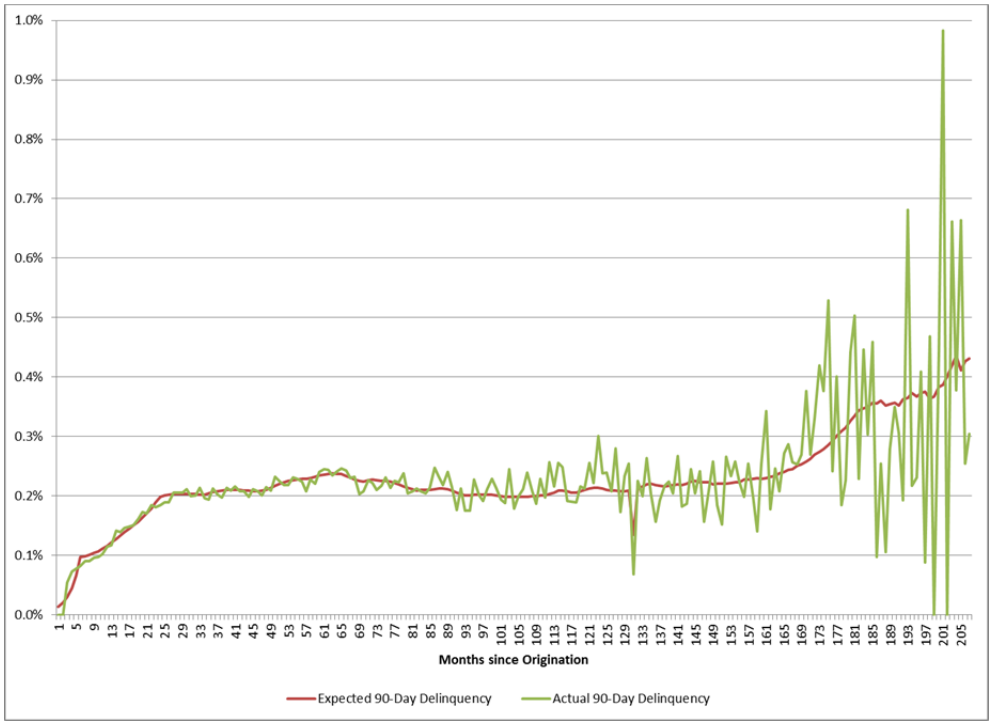
Notes: Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: FHFA

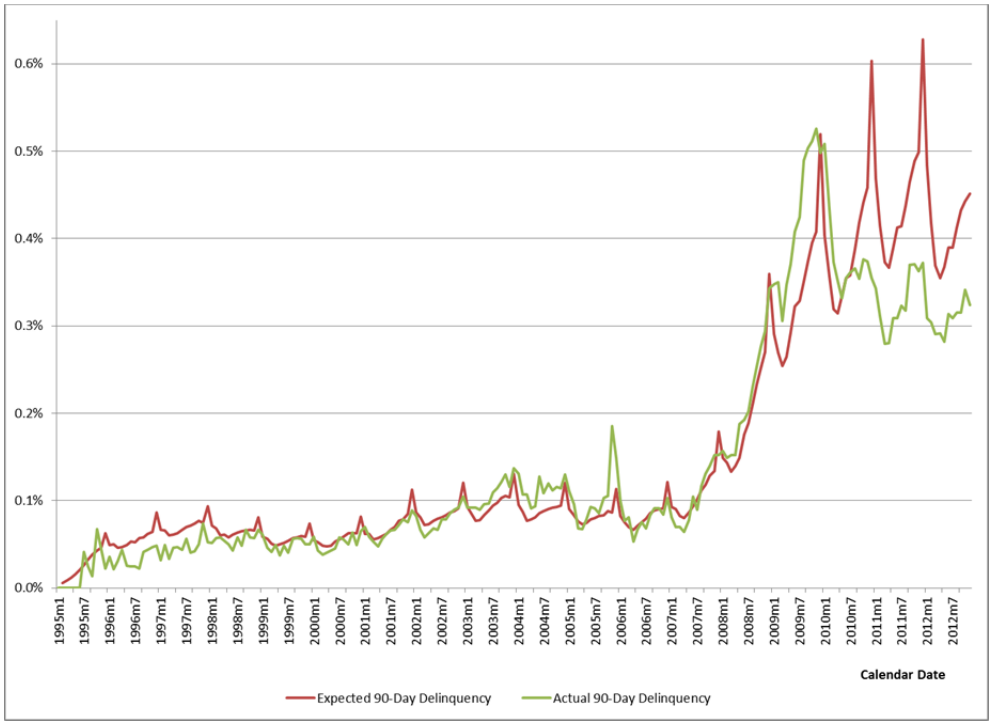
Appendix B

Exhibit B1: Monthly Average Conditional 90-Day Delinquent Rates, by Loan Age
GSE Market Segment



Source: FHFA

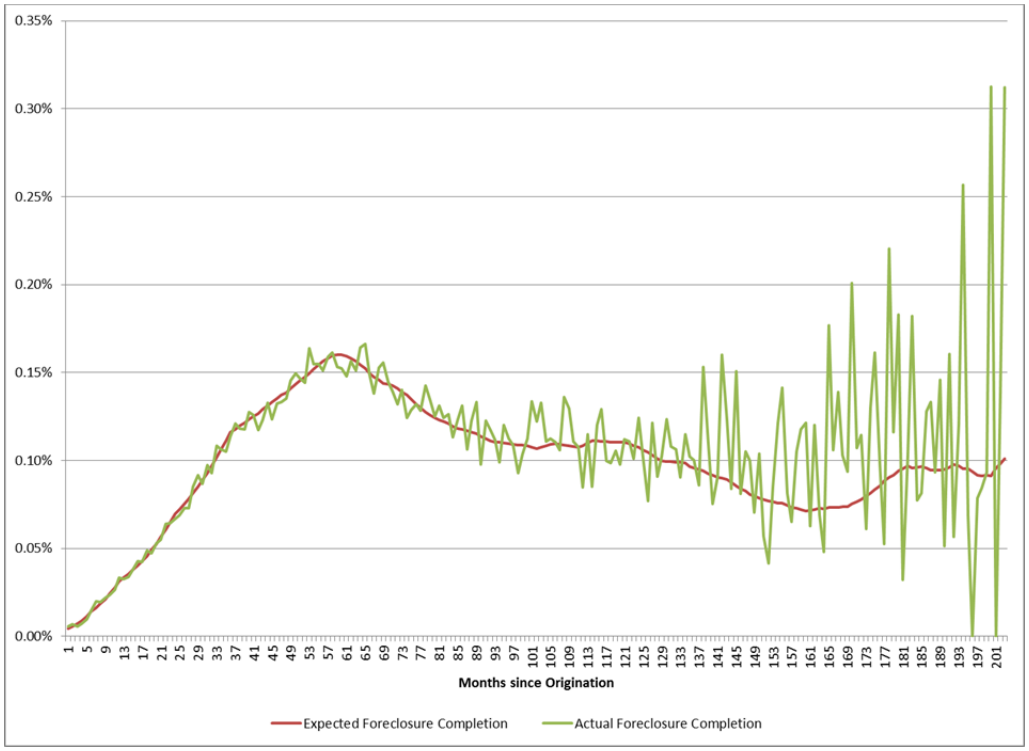
Exhibit B2: Monthly Average Conditional 90-Day Delinquent Rates, by Calendar Date
GSE Market Segment



Source: FHFA

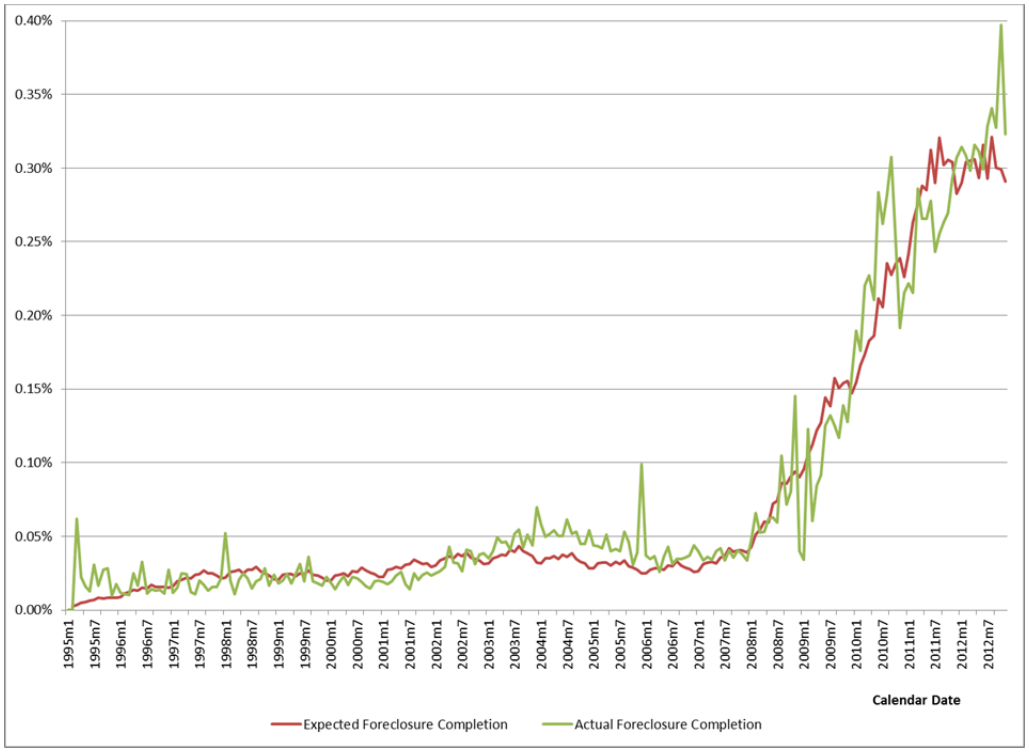
Note: We omitted to plot the observations for the last 3 months before the data cutoff due to the lack of data points.

Exhibit B3: Monthly Average Conditional Foreclosure Completion Rates, by Loan Age
GSE Market Segment



Source: FHFA

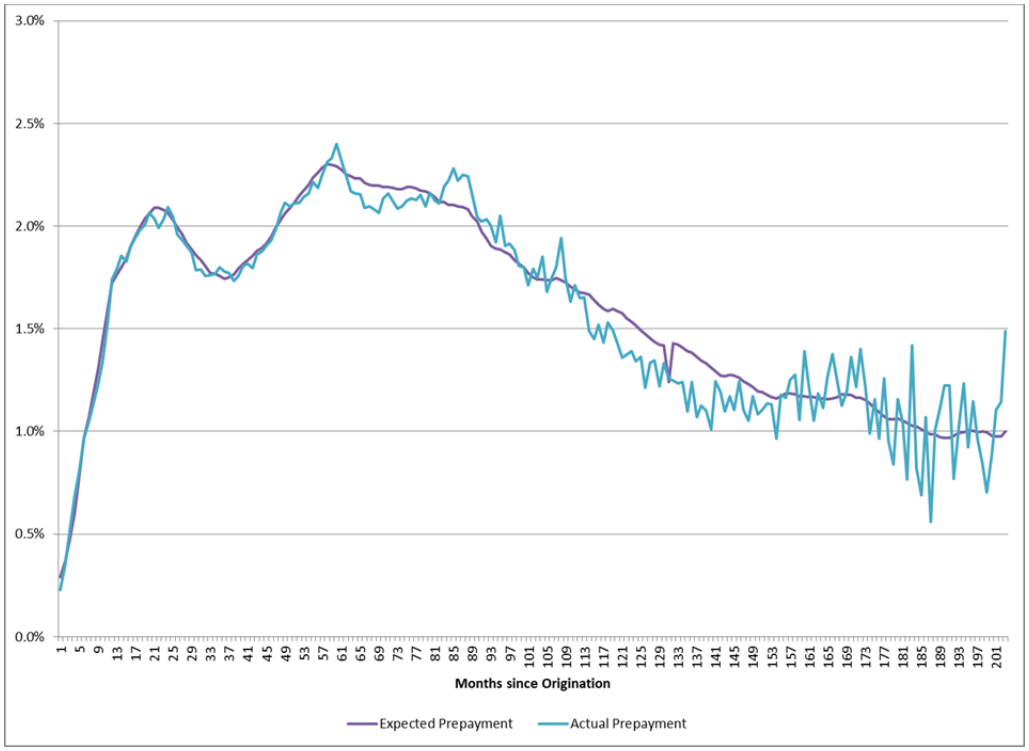
Exhibit B4: Monthly Average Conditional Foreclosure Completion Rates, by Calendar Date
GSE Market Segment



Source: FHFA

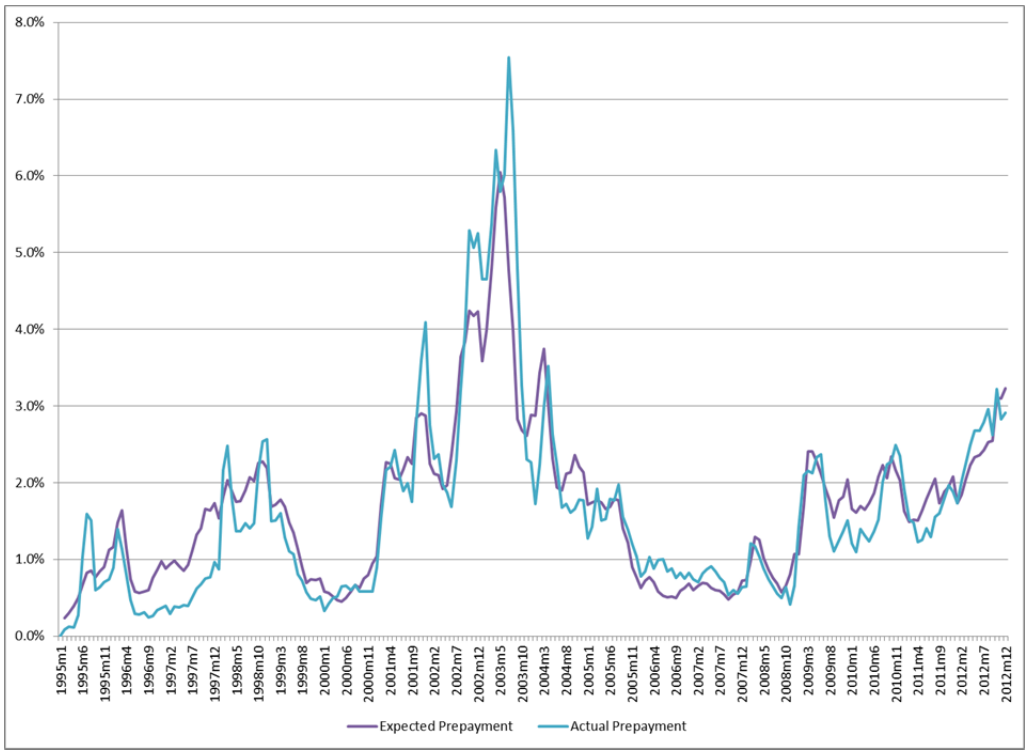
Note: We omitted to plot the observations for the last 3 months before the data cutoff due to the lack of data points.

Exhibit B5: Monthly Average Conditional Prepayment Rates, by Loan Age
GSE Market Segment



Source: FHFA

Exhibit B6: Monthly Average Conditional Prepayment Rates, by Calendar Date
GSE Market Segment

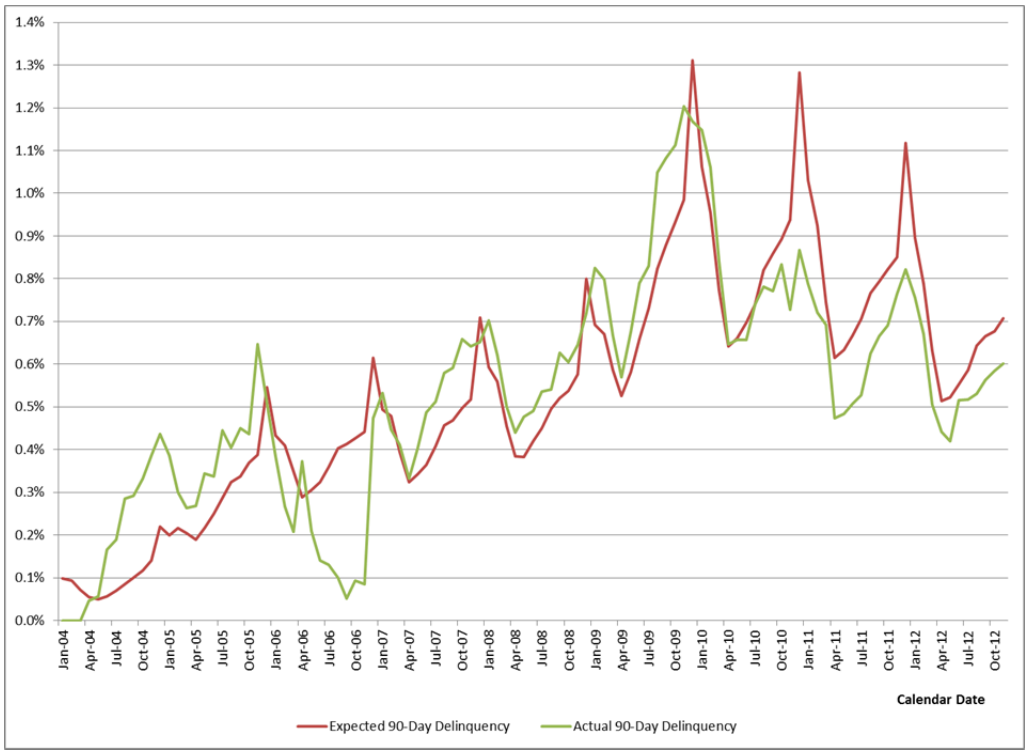


Source: FHFA

Exhibit B7: Monthly Average Conditional 90-Day Delinquent Rates, by Loan Age
FHA Market Segment

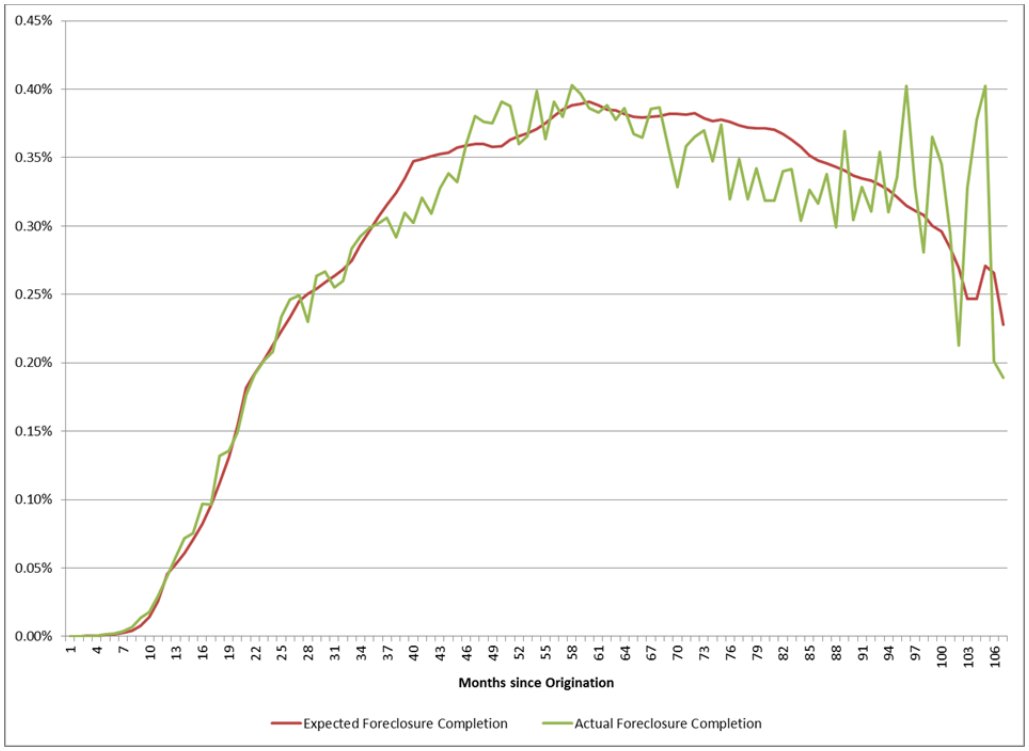
Source: FHFA

Exhibit B8: Monthly Average Conditional 90-Day Delinquent, by Calendar Date
FHA Market Segment



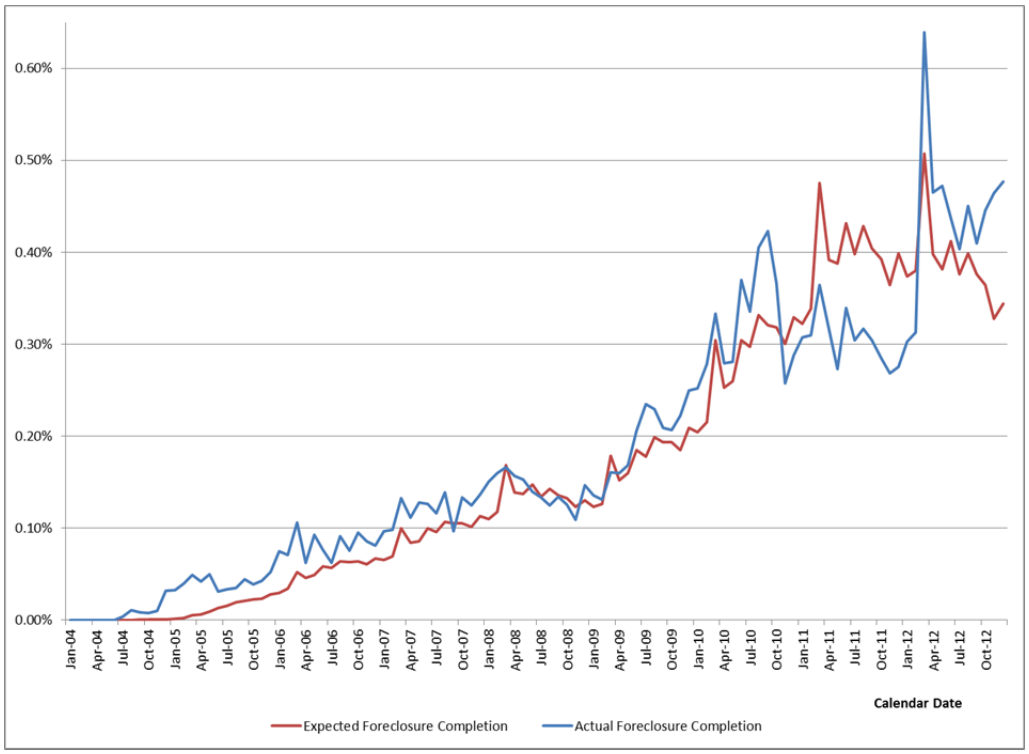
Source: FHFA

Exhibit B9: Monthly Average Conditional Foreclosure Completion Rates, by Loan Age
FHA Market Segment



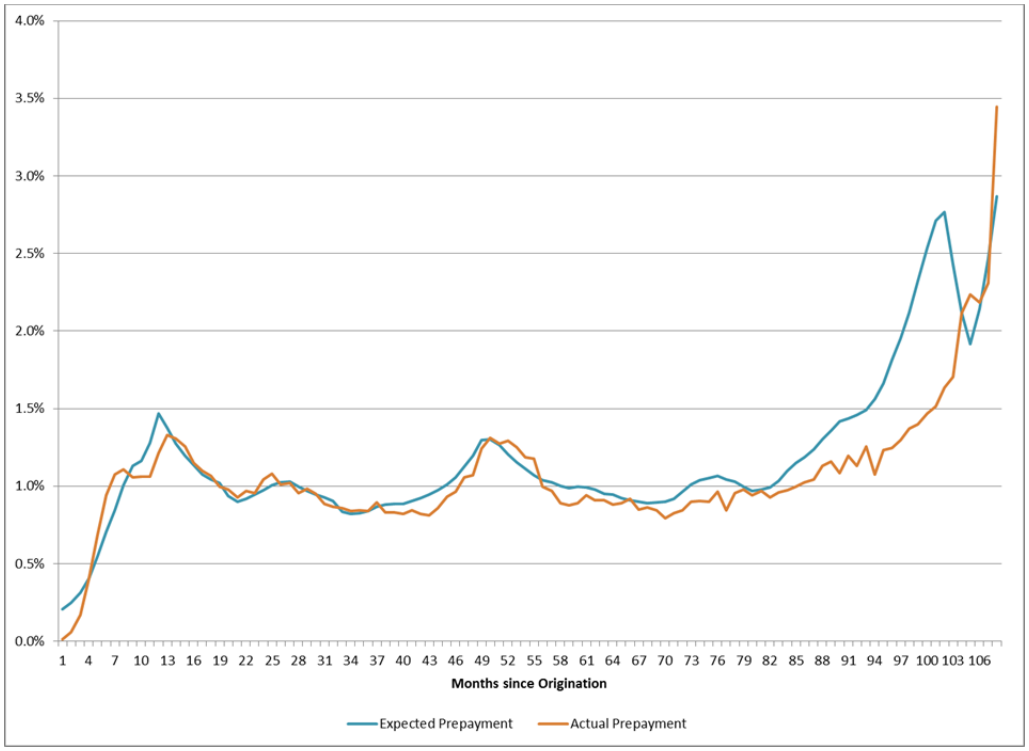
Source: FHFA

Exhibit B10: Monthly Average Conditional Foreclosure Completion Rates, by Calendar Date
FHA Market Segment



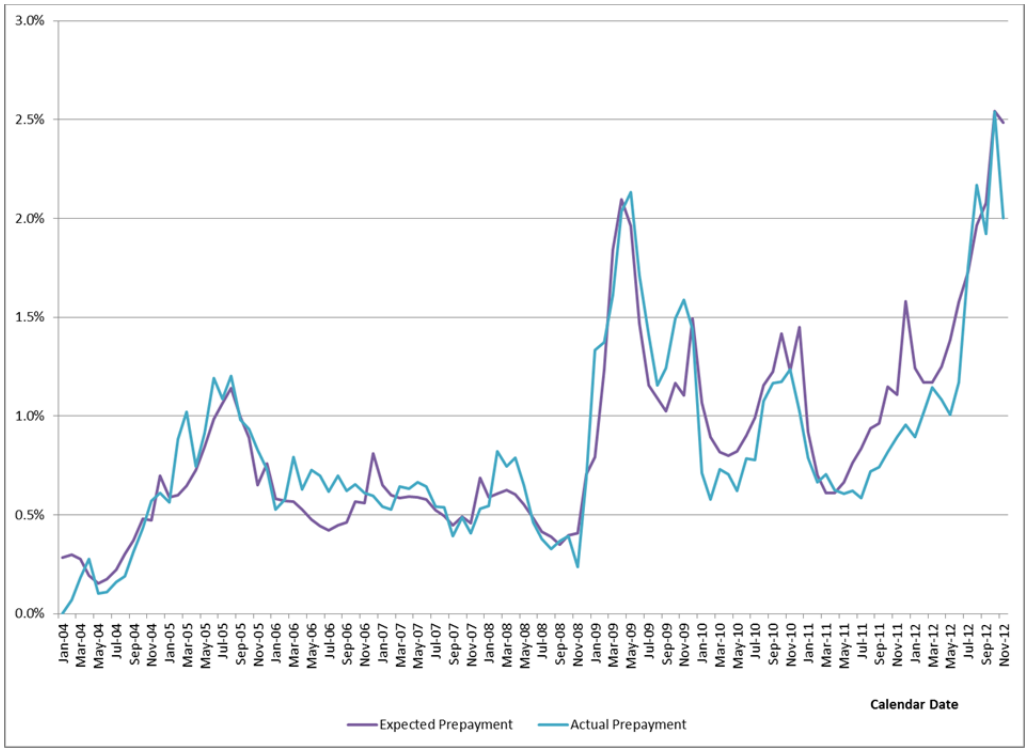
Source: FHFA

Exhibit B11: Monthly Average Conditional Prepayment Rates, by Loan Age
FHA Market Segment



Source: FHFA

Exhibit B12: Monthly Average Conditional Prepayment Rates, by Calendar Date
FHA Market Segment



Source: FHFA

Appendix C

Exhibit C1: LTV-Cumulative Foreclosure Completion rate Relationship, by DTI at Origination
Percentage Point Difference Estimates

Moody's Baseline Economic Scenario
FICO at Origination = 620; Baseline LTV = 80

	GSE Market Segment	
	DTI at Origination	
LTV at Origination	31	45
80	9.20%	10.52%
Ratio Between Foreclosure Rate of LTV=80% and Foreclosure Rate of Other LTV Categories		
70	-3.55%	-4.03%
85	2.02%	2.28%
90	4.46%	5.02%
95	7.35%	8.25%
100	10.57%	11.81%

	FHA Market Segment	
	DTI at Origination	
LTV at Origination	31	45
80	4.95%	5.45%
Ratio Between Foreclosure Rate of LTV=80% and Foreclosure Rate of Other LTV Categories		
70	-1.41%	-1.54%
85	1.37%	1.50%
90	3.08%	3.35%
95	7.46%	8.09%
100	9.05%	9.81%

Source: FHFA

Exhibit C2: LTV-Cumulative 90-Day Delinquency Rate Relationship, by DTI at Origination
Percentage Point Difference Estimates

Moody's Baseline Economic Scenario
FICO at Origination = 620; Baseline LTV = 80

	GSE Market Segment	
	DTI Ratio at Origination	
LTV at Origination	31	45
80	36.53%	45.18%
Percentage Point Difference Between Delinquency Rate of LTV=80% and Delinquency Rate of Other LTV Categories		
70	-7.00%	-8.06%
85	3.90%	4.36%
90	8.28%	9.15%
95	13.19%	14.37%
100	16.35%	17.68%

	FHA Market Segment	
	DTI Ratio at Origination	
LTV at Origination	31	45
80	42.75%	48.47%
Percentage Point Difference Between Delinquency Rate of LTV=80% and Delinquency Rate of Other LTV Categories		
70	-2.08%	-2.20%
85	1.05%	1.11%
90	2.21%	2.33%
95	9.19%	9.55%
100	10.54%	10.92%

Source: FHFA