

The Determinants of Subprime Mortgage Performance Following a Loan Modification

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Abstract We examine the evolution of mortgage modification terms obtained by distressed subprime borrowers during the recent housing crisis and the effect of the various types of modifications on the subsequent loan performance. Using the CoreLogic Loan Performance dataset that contains detailed loan level information on mortgages, modification terms, second liens, and home values, we estimate a discrete time proportional hazard model with competing risks to examine the determinants of post-modification mortgage outcomes. We find that principal reductions are particularly effective at improving loan outcomes, as high loan-to-value ratios are the single greatest contributor to re-default and foreclosure. However, any modification that reduces total payment and interest (P&I) reduces the likelihood of subsequent re-default and foreclosure. Modifications that increase the loan principal—primarily through capitalized interest and fees—are more likely to fail, even while controlling for changes in P&I.

Keywords Mortgage modification · Subprime · Mortgage default · Foreclosure · HAMP

JEL Classification D12 · G21 · R20 · R28

Introduction

Following the exuberant housing market of the mid-2000s, a national housing price collapse that began in 2007 resulted in many borrowers owing more on their mortgages than their homes were worth. This inability to pay off a mortgage with the proceeds from a home's sale, combined with widespread unemployment and declines in income, made many mortgages unsustainable for borrowers (Mayer et al. 2009). In response to the resulting millions of homeowners who defaulted on their mortgages and faced

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foreclosure, mortgage modifications were actively pursued by policymakers, consumer advocates, and, to a lesser extent, investors and mortgage servicers as a means of keeping borrowers in their homes.

Mortgage modifications, whereby the terms of the loan are altered in order to promote repayment by a distressed borrower, were relatively rare prior to the recent housing crisis. The vast majority of defaults self-cured, and foreclosure proceedings offered the lender or servicer a high recovery rate for the remaining loans (Ambrose and Capone 1996; Capone 1996; Adelino et al. 2009). This dynamic was altered during the housing crisis when mortgage default rates rose dramatically and the share of self-curing delinquent mortgages plummeted, particularly among subprime mortgages (Agarwal et al. 2011; Sherlund 2008). This increase in defaults, combined with plunging home values, changed the relative costs and benefits of providing alternatives to foreclosure, including mortgage modifications (Cutts and Merrill 2008).

Early in the housing crisis, the parameters of mortgage modifications, including when they were even offered, varied widely depending on the mortgage servicer (Agarwal et al. 2011). Moreover, the mortgage modifications made in 2008 often failed to lower monthly payments for the borrower, with approximately half of all modifications in the subprime and alt-a market yielding payment increases (White 2009). Similarly, data from the Office of the Comptroller of the Currency's (OCC) mortgage metrics report, which includes prime loans and covers approximately two-thirds of all first-lien mortgages outstanding in the United States, show that, in 2008, 32 % of modified loans resulted in an increase in monthly payments and 42 % in a decrease in the monthly payments (Office of the Comptroller of the Currency 2009). As these early mortgage modifications rarely improved the affordability of the mortgage payment, the loans were highly likely to re-default following the modification: Over 60 % of mortgages modified in 2008 had re-defaulted within 12 months (Goodman et al. 2011).

As part of the policy response to the financial crisis, the federal government allocated billions of dollars to programs aimed at assisting homeowners in distress. These programs included the Home Affordable Modification Program (HAMP), introduced in March 2009, which provided incentive payments to mortgage lenders, servicers, borrowers, and investors for modifying loans to conform to the HAMP guidelines. The primary requirement was that the first lien mortgage payment be reduced to 31 % of the borrower's income; however, the terms of the loan that are modified in order to achieve the reduction in payment varied from borrower to borrower. The intent of the HAMP payment reduction requirement was to improve the affordability of the mortgage for distressed borrowers and thus improve their chances of remaining in their homes.

Following the introduction of HAMP, an increasing share of modified loans received payment decreases, regardless of whether or not they qualified as HAMP modifications. In the first quarter of 2009, 53 % of modifications involved a payment reduction; by the second quarter of 2009, 78 % of modifications involved a payment reduction. Thereafter, the percent of modifications involving a reduction in the monthly payment continued to increase, reaching approximately 93 % by the fourth quarter of 2012 (Office of the Comptroller of the Currency 2013). While many mortgage modifications since the implementation of HAMP are not classified as resulting directly from the program, the standard terms offered on these proprietary modifications changed following HAMP's implementation (Goodman et al. 2011).

The number of mortgage modifications increased substantially beginning in 2009 and peaked at over 250,000 in the second quarter of 2010 (Goodman et al. 2012; Office of the Comptroller of the Currency 2011). While the number of modifications each quarter has generally decreased since mid-2010, as of the second quarter of 2014, 2.49 % of residential mortgages were still at some stage of the foreclosure process and 6.04 % were at least one payment past due but not in foreclosure (Mortgage Bankers' Association 2014). Thus, mortgage modifications continue to play an important role in the recovery of the housing market, and it is therefore important to understand what aspects of modifications are most successful at allowing the borrower to avoid default and foreclosure.

Despite the important role that mortgage modifications have played in the response to the housing crisis, relatively little research examines which types of mortgage modifications are the most successful at avoiding subsequent re-default and foreclosure. While a handful of studies examined post-modification loan performance, that research has either tended to focus on narrow geographic areas (Voicu et al. 2012a) or only pre-HAMP loan modifications (Quercia and Ding 2009; Haughwout et al. 2009; Agarwal et al. 2011). This study augments the existing literature by examining post-modification loan performance for a national sample of subprime loans using a rich dataset that includes information on junior liens, current property valuations, and detailed information on the parameters of loan modifications. Specifically, we examine whether reductions in principal, interest rate, or P&I, are most effective at reducing subsequent re-default and foreclosure. Using loan-level data from CoreLogic's Loan Performance Asset Backed Securities (ABS) data on privately securitized subprime mortgages originated from 2000 through 2007, we find that principal reductions are the most effective type of modification, as they generally lower the borrower's monthly payment and reduce the loan-to-value (LTV) ratio in addition to having an independent effect on re-default. However, any modification that improves the affordability of the mortgage, such as a reduction in the monthly P&I, reduces the probability of subsequent re-default and foreclosure. Our results provide insights to loan servicers, mortgage investors, and policymakers as to the relative effectiveness of the various types of loan modifications, allowing them to more accurately assess the cost of a modification relative to the cost of a foreclosure.

Previous Literature

A large body of literature exists on the determinants of mortgage default for prime mortgages (Deng et al. 2000; Phillips and VanderHoff 2004; Quercia and Stegman 1992; Ambrose et al. 1997) and subprime mortgages (Kau et al. 2011; deRitis et al. 2010; Danis and Pennington-Cross 2008) prior to the housing crisis. However, from the 1990s through the mid-2000s, mortgage underwriting standards declined substantially, resulting in an unprecedented national wave of defaults and foreclosures when house prices subsequently fell and economic conditions deteriorated (Demyanyk and Van Hemert 2011; Haughwout et al. 2008; Mian and Sufi 2009).

With this wave of mortgage defaults, researchers turned their attention to analyzing mortgage outcomes for borrowers in default, with an emphasis on whether the loan terminated in foreclosure or received a modification. These studies identified a wide

range of factors that affect mortgage outcomes, with state laws governing foreclosure, the amount of home equity, credit scores at origination, and the presence of junior liens among the most significant (Voicu et al. 2012b; Chan et al. 2014; Gerardi et al. 2013b). Interventions, such as mortgage default counseling, were also shown to substantially increase the probability that a borrower receives a loan modification and reduces the probability of foreclosure (Collins and Schmeiser 2013; Collins et al. 2013).

While the literature on outcomes for loans in default following the housing crisis has provided significant insight into the determinants of receiving a loan modification, a much smaller body of literature has examined the parameters of mortgage modifications and how they affect subsequent loan performance. Among the earliest studies of post-modification loan performance was Quercia and Ding (2009), who used a national sample of subprime and alt-a securitized mortgages drawn from the Columbia Collateral File that were modified in 2008. They found that the greater the reduction in the monthly payment, the lower the likelihood that the mortgage would re-default by December 2008. Payment reductions achieved through a combination of rate and principal reductions were most effective at reducing re-default, followed by rate reductions alone.

Many of the subsequent studies focused on analyzing the performance of pre-HAMP loan modifications. For example, Haughwout et al. (2009) used the CoreLogic Loan Performance data on subprime and alt-a securitized loans to analyze the determinants of post-mortgage modification re-default prior to the implementation of HAMP. Using a proportional hazard framework, they find that the greater the reduction in the monthly payment, the lower the likelihood that the mortgage re-defaults. Further, they find that having a negative equity position substantially increases the probability of re-default.

Agarwal et al. (2011) also focused on mortgage modifications that occurred prior to the introduction of HAMP. Using the OCC Mortgage-Metrics database, they estimate the probability that a loan re-defaults (60 plus days delinquent) within six months of a modification, and find that the probability of re-default declines the more monthly payments are reduced, and that re-default rates increase as LTV increases. They also find that the servicer of the mortgage has a significant effect on the ultimate success of the modifications, even after controlling for the terms of the modification.

One of the only studies to examine mortgage modifications both pre- and post-HAMP was done by Voicu et al. (2012a). Focusing only on the New York City area, they find that modifications where the interest rate or principal are reduced are less likely to re-default. Further, they find that HAMP modifications perform better than proprietary modifications, although they are unable to determine what aspects of HAMP yield better loan performance.

Our research expands on this existing literature in several ways. First, we use a sample of subprime and alt-a mortgages drawn from across the United States rather than one specific geographic area. Second, we examine both HAMP and proprietary mortgage modifications from 2008 through 2013 and follow their performance through the fourth quarter of 2013. Finally, using a discrete time proportional hazard framework, we control for the full range of information CoreLogic collects on the loans, including the presence and amount of any junior liens, a current property value generated using an automated valuation model (AVM), and detailed terms for the mortgage modifications.

Data

The data for this study come from CoreLogic's Loan Performance ABS data on privately securitized mortgages. The CoreLogic ABS data include information on subprime and alt-a loans but do not include information on agency-backed securities or loans held in portfolio.¹ As of 2010, these data contained monthly performance history for about 20 million individual loans. The CoreLogic data used in this paper are only representative of privately securitized subprime and alt-a loans, not the entire U.S. mortgage market. While the coverage of these data may limit the generalizability of our findings, these loans are of particular interest to investors and policymakers given the high incidence of default, foreclosure, and modification in this population.

The CoreLogic data contain detailed static and dynamic information on the loans and their performance. The static data include information from origination such as date of origination, the zip code where the property is located, the borrower's FICO score, origination balance, interest rate, P&I amount, and servicer. The dynamic data are updated monthly and include information on the current interest rate, mortgage balance, payment amount, and loan performance.

CoreLogic also provides two supplemental files that are used in our analysis. The first contains detailed information on whether a borrower received a loan modification, as well as the parameters of the modification (for example, reduction in principal, reduction in interest rate, or change in amortization term). While CoreLogic does not explicitly identify a loan as being a HAMP modification, we infer whether or not the loan was modified under HAMP by whether the characteristics of the modification follow the HAMP program waterfall for reducing the monthly payment, such as reducing the interest rate to 2 % and then extending the term of the loan once the 2 % floor is reached. The second file is the CoreLogic TrueLTV Data, which matches the loans in the CoreLogic Loan Performance data to public records to obtain information on subsequent liens taken out on the property. These data also contain a monthly estimate of the property's value from their AVM. The combination of monthly data on the value of all liens on the property with the monthly estimate of the property's value from the AVM allows for the computation of a current combined loan-to-value (CLTV) ratio.

The ability to include a current estimate of CLTV based on the inclusion of junior liens in the loan amount and a value estimated specifically for that property represents a major improvement over previous studies. Past research has largely excluded junior liens from the loan amount and has been limited to the inclusion of metropolitan statistical area (MSA) level price indices or adjusting the appraised value at origination by some price index to capture current property value.

Given the number of loans in the CoreLogic ABS data, we select a 5 % random sample from the universe of first-lien mortgages. Our data on modifications and loan performance cover the period from January 2008 through December 2013. We restrict our data to loans originated no earlier than January 2000 and modifications occurring after January 2008. To provide economic context for the loan performance, we merge in monthly state-level unemployment rates obtained from the Bureau of Labor

¹ CoreLogic also has a separate database on privately securitized prime and/or jumbo loans; however we restrict our analysis sample to the subprime and alt-a loan data.

Statistics. Finally, in order to proxy for local housing market conditions and borrowers' expectations for future house price changes, we include the year-on-year percent change in the property ZIP code's House Price Index (HPI) from CoreLogic.

After we merge our 5 % random sample of the CoreLogic ABS data with the supplemental loan modification file and drop all observations for loan identification (ID) numbers that have no modifications over the course of our study period, we have approximately 2.3 million loan month observations from approximately 64,000 individual loans. After dropping observations with missing data, we are left with 37,027 unique loans. Figure 1 plots the number of mortgage modifications occurring each month in our sample over the period from January 2008 to December 2013. The number of monthly modifications peaked in early 2009, just prior to the enactment of HAMP, before plummeting.² The number of modifications increased sharply again in early 2010, and since then it has largely declined.

Figure 2 plots the terminal outcomes for all of the modified loans in our data over time. The graph shows that real estate owned (REO) is the most likely terminal outcome for a modified loan in our sample, except for two short periods in 2012 and 2013. The peak of foreclosure occurred at the end of 2011 and has fluctuated below that peak in the time since. Short sales and foreclosure sales increased to a peak at the end of 2012 and appear to have declined in the months after, while payoffs have remained relatively flat over the sample period.

Figure 3 shows a survival graph for the share of loans that remain current or 30 days delinquent in the months following a modification. The survival rates to 60 plus days delinquent are plotted separately by the year in which the mortgage received its first modification to illustrate the substantial variation in subsequent loan performance. The rate at which loans become 60 plus days delinquent following a modification declines substantially in each successive year from 2008 to 2012. For loans first modified in 2008, over 60 % had re-defaulted within 12 months of the modification. In contrast, for loans first modified in 2012, the 12-month re-default rate had declined to only 20 %.

The top panel of Fig. 4 shows the percentage of modified loans receiving either a principal increase or decrease over the sample period. From 2008 until 2012, a loan modification was far more likely to result in an increase in the mortgage principal balance than to result in a decrease in mortgage principal, as fees and accrued interest were often rolled into the modified principal amount. From 2009 through 2010, approximately 80 % of modifications resulted in the mortgage principal increasing, thereafter declining until reaching less than 40 % in late 2012. The share of modifications resulting in principal decreases rose steadily throughout the sample period, and by mid-2012 actually exceeded the share of loans with principal increases. Since mid-2012, the share of modified loans in our sample involving a principal reduction has consistently exceeded 40 %.

The bottom panel of Fig. 4 shows the percentage of modified loans that yield either an increase or decrease in the monthly payment amount. Throughout the study period, the majority of modifications have resulted in a reduction in monthly borrower payments. The share of borrowers whose monthly payment was lowered has increased over time, rising from around 50 % in January 2008 to just below 80 % in October 2013.

² This drop in modifications may be partially attributable to mortgages qualifying for HAMP modification and entering their three-month trial period, as HAMP modifications are not counted until they are made permanent.

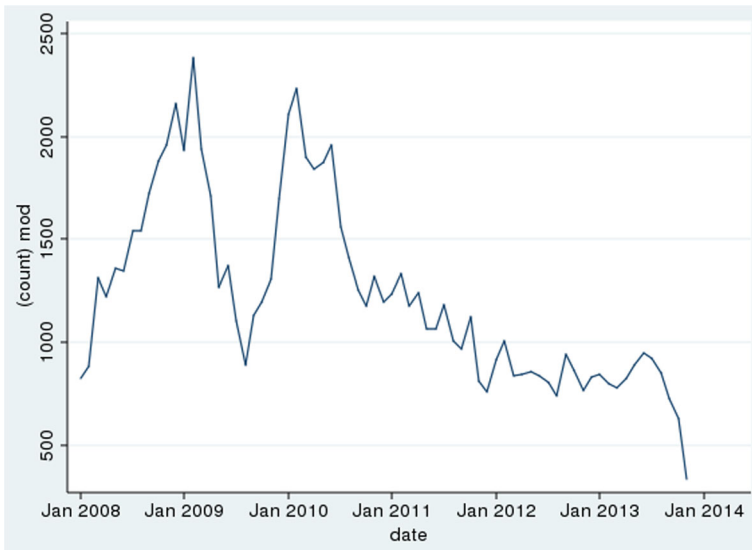


Fig 1 Number of mortgage modifications per month for the sample

As found in the previous literature, the typical modification received by borrowers varies substantially over time, with the launch of the HAMP program corresponding to a change in the terms of modifications. Prior to the implementation of HAMP in March 2009, 21 % of modifications resulted in a P&I increase and 73 % a P&I decrease, and 79 % resulted in an increase in the principal balance, while only 4 % resulted in a reduction in principal. For those whose P&I was reduced, the average reduction was 17 % of the pre-mod P&I. Post-HAMP, the share of modifications that resulted in a P&I increase fell to 11. While 69 % of modifications still resulted in an increase in the principal balance following the introduction of HAMP, the share where the principal

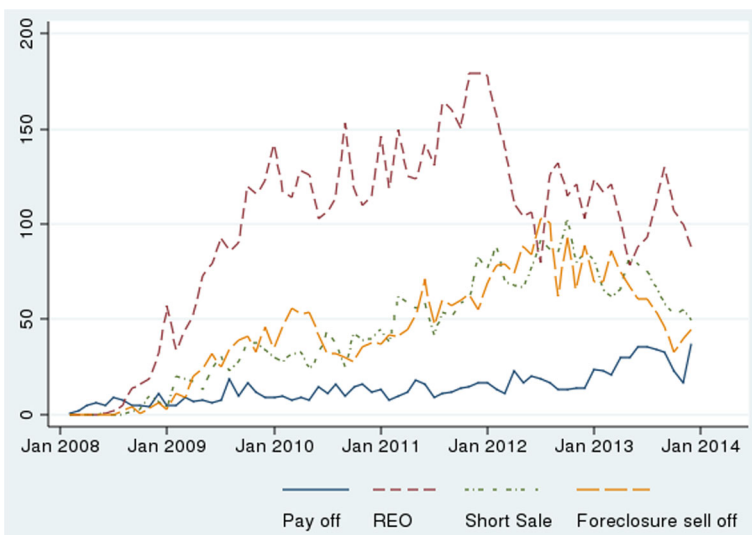


Fig 2 Number of mortgage terminations per month by termination type, for the sample

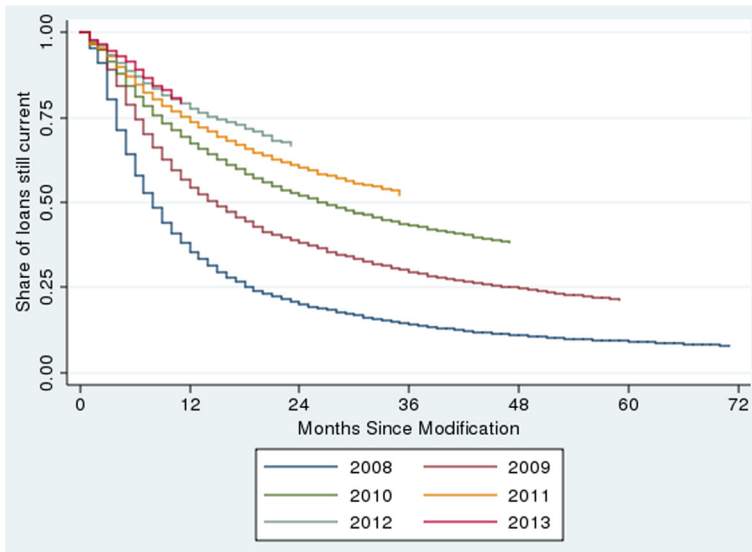


Fig 3 Kaplan-Meier survival graph for mortgage performance, by year of modification Notes: Failure is defined as the mortgage reaching 60 plus days delinquent post-modification. Analysis time begins at the month of modification.

was reduced increased to 22 %. Moreover, among those receiving a principal reduction, the average amount went from \$17,253 pre-HAMP to \$65,633 post-HAMP. The share of loans that involved a reduction in the interest rate increase only slightly from pre- to post-HAMP, going from 82 % to 87 % of modifications.

Table 1 presents descriptive statistics for the first modification experienced by each mortgage in our analysis sample. We further present summary statistics separately for non-HAMP and HAMP modifications. The subprime nature of our sample is apparent from the average characteristics at the time of origination: 50 % had low or no documentation and the average FICO score was 638. Nearly three-fourths of the mortgages were originated in either 2005 or 2006, and 62 % were refinancings. The majority of first modifications were performed from 2008 to 2010, with only 29 % occurring in 2011 through 2013. Almost 23 % of the first modifications in our sample are classified as HAMP modifications.

On average, 15 % of first modifications resulted in a P&I increase, 80 % resulted in a P&I decrease, and the remaining 5 % experienced no change in P&I. For those loans where the P&I was reduced, the average decrease was \$949. The reduction in P&I was largely driven by a reduction in the interest rate on the loan, with an average rate reduction of 3.9 percentage points. Nearly three-fourths of the first modifications in our sample result in an increase in principal balance, consistent with Fig. 4 and the OCC Mortgage Metrics reports. Almost 16 % of modifications, and 36 % of HAMP modifications, resulted in a principal reduction, with an average reduction of \$76,000 and \$83,000, respectively, among those loans where the principal was reduced. The average principal balance post-modification was \$265,000, and 45 % of the sample had a junior lien at the time of modification. Overall, the average CLTV barely changed before and after the modification, remaining at 115 %, meaning that even after a modification the average homeowner was underwater on his mortgage. Moreover, almost 16 % of those receiving a modification had a CLTV greater than 150 % after their modification.

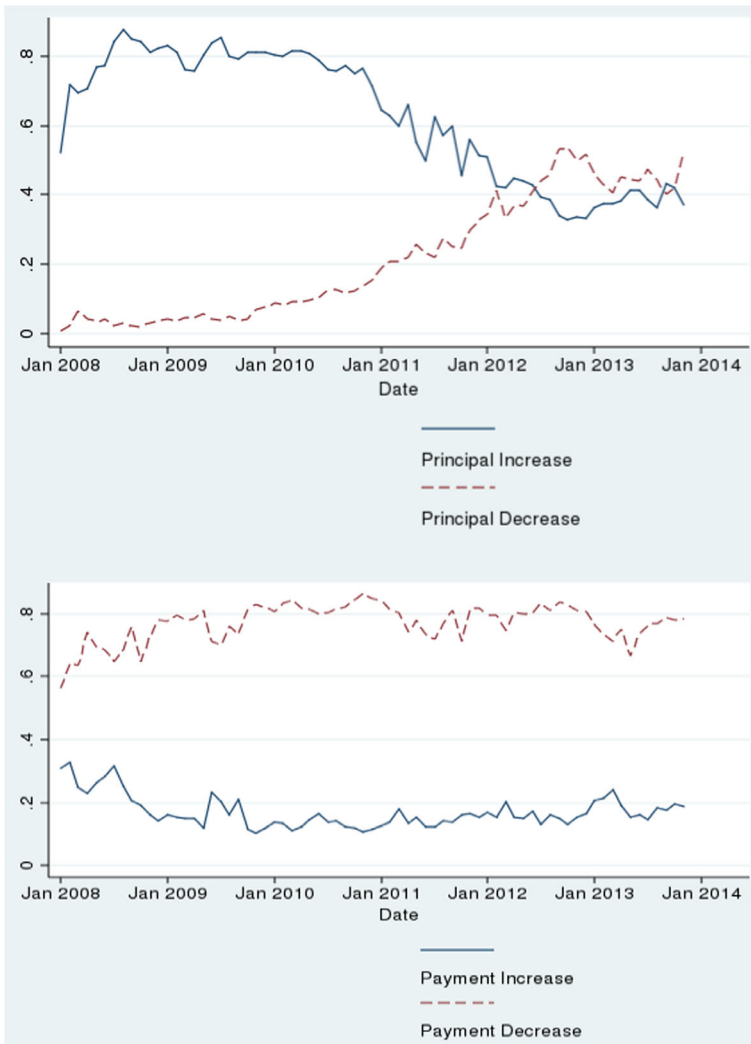


Fig 4 Share of sample loan modifications where borrower has their principal increased/decreased (top) and payment increased/decreased (bottom), by date of modification

Empirical Model

We begin our analysis of how the various types of loan modifications affect subsequent loan performance by using a simple probit model to estimate the probability that a loan reaches 60 plus days delinquent within 12 months following a loan modification. Our probit model takes the form:

$$\Pr(Y_{i,t} = 1) = f(\alpha + \beta X_i + \gamma Mod_i + \delta CLTV_i + \pi HPI_z + \theta State_s + \varepsilon_{is})(1)$$

where Y is an indicator for whether or not the loan becomes 60 plus days delinquent within 12 months and X is a vector of loan characteristics from origination, including an indicator for whether the loan was used for a home purchase, categories for the

Table 1 Descriptive statistics

	Full sample		Non-HAMP		HAMP	
	Mean	SD	Mean	SD	Mean	SD
Junior lien	0.4453	0.4970	0.4464	0.4971	0.4414	0.4966
Loan used for purchase	0.3770	0.4846	0.3909	0.4880	0.3297	0.4701
Not owner occupied	0.0457	0.2088	0.0512	0.2205	0.0267	0.1614
Low or no documentation	0.4966	0.5000	0.4567	0.4981	0.6333	0.4819
Judicial foreclosure state	0.3786	0.4851	0.3765	0.4845	0.3859	0.4868
State with redemption law	0.4624	0.4986	0.4457	0.4970	0.5199	0.4996
Non-recourse state	0.5800	0.4936	0.5647	0.4958	0.6321	0.4823
Current at time of mod	0.2646	0.4411	0.2839	0.4509	0.1987	0.3990
30 to 60 days delinquent at mod	0.1320	0.3385	0.1491	0.3562	0.0734	0.2609
90 days delinquent at mod	0.4949	0.5000	0.4658	0.4988	0.5944	0.4910
Lis pendens at mod	0.1085	0.3110	0.1012	0.3016	0.1335	0.3401
Originated 2004	0.0831	0.2761	0.0888	0.2845	0.0636	0.2441
Originated 2005	0.2834	0.4506	0.2937	0.4555	0.2480	0.4319
Originated 2006	0.4575	0.4982	0.4531	0.4978	0.4725	0.4993
Originated 2007	0.1411	0.3481	0.1272	0.3332	0.1885	0.3912
First modified in 2008	0.2522	0.4343	0.3260	0.4687	0.0000	0.0000
First modified in 2009	0.2166	0.4119	0.2564	0.4366	0.0805	0.2720
First modified in 2010	0.2417	0.4281	0.2018	0.4014	0.3783	0.4850
First modified in 2011	0.1336	0.3402	0.1025	0.3033	0.2398	0.4270
First modified in 2012	0.0929	0.2903	0.0652	0.2469	0.1875	0.3903
First modified in 2013	0.0630	0.2430	0.0481	0.2140	0.1140	0.3179

Table 1 (continued)

	Full sample		Non-HAMP		HAMP	
	Mean	SD	Mean	SD	Mean	SD
FICO at origination	638.13	64.99	632.50	64.00	657.37	64.65
HAMP modification indicator	0.2262	0.4184	0	0	1	0
Monthly P&I pre-modification (\$)	1,684.68	1,669.09	1,644.52	1,015.80	1,822.08	2,960.24
Reduction in P&I (\$)	-949.71	642.40	-733.38	562.82	-1087.37	651.98
Percent increase in P&I	12.6513	15.1130	12.6513	15.1130	0	0
Percent reduction in P&I	51.0829	18.1567	40.1092	16.9409	58.0655	15.2151
Interest rate pre-modification	7.3324	2.0602	7.6268	1.9475	6.3254	2.1166
Reduction in interest rate	-3.8507	1.9835	-2.8799	1.6738	-4.4685	1.9169
Percent reduction in interest rate	54.1990	21.0554	36.9976	18.5380	65.1443	14.0966
Principal balance pre-modification (\$)	264,570	173,884	250,521	167,999	312,634	184,762
Principal balance post-modification (\$)	265,116	184,156	255,899	182,766	296,648	185,412
Reduction in principal (\$)	-76,179	74,104	-65,659	68,839	-82,872	76,529
Principal decrease indicator	0.1579	0.3646	0.099	0.2987	0.3593	0.4798
Percent reduction in principal	25.4183	16.4989	23.9376	15.6324	26.3604	16.9628
Principal increase indicator	0.7266	0.4457	0.7739	0.4183	0.5648	0.4958
Loan to value ratio pre-modification	115.09	38.34	111.75	35.97	126.52	43.62
Loan to value ratio post-modification	115.30	70.19	113.61	75.51	121.09	47.27
CLTV 150 % and above	0.1555	0.3624	0.1276	0.3337	0.2509	0.4335
Year on year change in HPI (%)	-6.14	10.07	-7.59	10.16	-1.17	7.95
Unemployment rate at modification	8.83	2.42	8.50	2.44	9.99	1.98
Number of loans	37,027		28,652		8,375	

borrower's FICO score, whether the home was owner-occupied, whether the loan had low or no documentation, and indicators for the origination year. Mod is a vector of loan characteristics at the time of modification, including loan servicer fixed-effects, indicators for the payment status of the loan with current as the omitted category, an indicator for whether the property has a junior lien, and modification year indicators. Mod further includes the key characteristics of the mortgage modification of interest for our analysis: whether it is a HAMP modification, the percent reduction in principal, an indicator for having an increase in principal, the percent reduction in P&I, the percent increase in P&I, and the percent reduction in the interest rate. We further include the CLTV ratio at the time of modification in categories with less than 80 % used as the omitted category. HPI is the year-on-year percent change in the CoreLogic HPI for the property ZIP code at the time of modification. Finally, State is a vector of indicators for whether the property is in a judicial foreclosure, redemption law, or non-recourse state. The probit model is run as a cross-sectional analysis using only the covariate values from the time of the modification. Moreover, state fixed-effects are omitted so as to allow the inclusion of the various state-specific mortgage laws.

We supplement this probit analysis with a discrete time proportional hazard framework with competing risks analysis of how the various modification parameters affect mortgage performance and mortgage outcomes over the entire post-modification period. This strategy also allows us to take advantage of time variation in variables such as the CLTV and the state unemployment rate.

Once a borrower receives a modification, he should be current on his payments in the month following the modification, creating a good origination point to compare the outcomes of modified loans. Since we focus only on modified loans, we drop all mortgages that do not receive modifications over the course of our sample period. The status of a mortgage in our sample in a given month can take on one of a number of different discrete states. We categorize the set of possible states into six options: current or 30 days delinquent, 60 plus days delinquent, foreclosure filing (*lis pendens*), REO/sale out of foreclosure, short payoff, or re-modification. REO and sale out of foreclosure are combined into one outcome since they are equivalent from the borrower's perspective, both resulting in the loss of the home. Since so few borrowers who received a modification prepaid their mortgage in full, we simply dropped them from the sample.

We structure our data in event history format so as to estimate our proportional hazard model using a standard multinomial logit. Months since modification is then included as a covariate to allow for time dependence of the hazard rate. We include as covariates the same loan characteristics from origination used in the probit analysis: an indicator for whether the loan was used for a home purchase, categories for the borrower's FICO score, whether the home was owner-occupied, whether the loan had low or no documentation, and indicators for the origination year. The loan-level covariates from the time of modification again include loan servicer fixed-effects, indicators for the payment status of the loan at modification, an indicator for whether the property has a junior lien, modification year indicators, and indicators for whether the property is in a judicial foreclosure, redemption law, or non-recourse state. We then include the characteristics of the mortgage modifications: being a HAMP modification, the percent reduction in principal, an indicator for having an increase in principal, the percent reduction in P&I, the percent increase in P&I, and the percent reduction in the

interest rate. However, in the proportional hazard framework we allow the CLTV ratio to vary over time as the house price and loan balances change. We further include the monthly state unemployment rate to capture changes in the economic conditions faced by the borrower, and the ZIP code level percent change in HPI over the past 12 months.

To evaluate whether or not the performance of HAMP modifications differs from that of proprietary modifications, we re-estimate our proportional hazard model on the sample limited to non-HAMP and then HAMP modifications. When the sample is limited to non-HAMP modifications, the covariates included in the analysis remain identical to those for the full sample, with the exception of the removal of the HAMP indicator. When the sample is limited to HAMP modifications, we also drop the indicator for first modification occurring in 2009 and use that as the reference category, and drop the percent increase in P&I, as none of the HAMP modifications resulted in a higher P&I for the borrower. Moreover, the sample period now begins in April 2009, as no HAMP modifications occurred prior to that date.

Results

Table 2 presents the results of our probit analysis of the effect of the various modification parameters on the 12-month probability of re-default. Of the key mortgage modification parameters of interest, the coefficients on reduction in the P&I and the interest rate have the greatest magnitude and are statistically significant. A 1% reduction in P&I is estimated to reduce the probability of re-default by 0.23 percentage point, while a 1% reduction in the interest rate reduces the probability of re-default by 0.17 percentage point. From Table 1, the average P&I reduction was 51% and the average interest rate reduction was 54% among those who received a reduction. Overall, 39% of the loans in our estimation sample become 60 days or more delinquent within only 12 months of receiving a loan modification, suggesting that the average reduction in P&I reduced re-default by 30%, and the average interest rate reduction reduce re-default by 23%. The magnitude of coefficient on the percent principal reduction is somewhat less than that for P&I and interest rate, with that a 1% reduction in the principal balance estimated to reduce the 12-month re-default rate by 0.14 percentage points. With an average reduction in principal of 25% for those who received a reduction, this translates into a 9% lower probability of re-default. This is in addition to the effect of principal reductions that operates through a reduction in the P&I and the CLTV. While HAMP mods appear to be somewhat less likely to re-default, the coefficient is only marginally significant.

The probit results also suggest what types of modifications are particularly prone to failure. In particular, a modification that increases the mortgage principal increases the probability of re-default within 12 months by 1.9 percentage points, or 5%, while a 1 percentage point increases in the P&I increases the probability of re-default within 12 months by 0.13 percentage point, or 4% given an average increase in P&I of 13%. Loans that are severely delinquent or in foreclosure at the time of modification are, unsurprisingly, the most prone to re-default, with a loan modified when 90 plus days delinquent being 11 percentage points more likely to re-default within 12 months, and a loan modified when in the foreclosure process being 15 percentage points more likely to re-default.

Table 2 Determinants of mortgage default post modification

All modifications	60+ days delinquent within 12 months
Junior lien	0.0280*** (5.3485)
Loan used for purchase	0.0427*** (8.2310)
FICO at origination 580 to 649	-0.0462*** (-7.0780)
FICO at origination 650 to 719	-0.1347*** (-17.8363)
FICO at origination 720 and above	-0.2253*** (-22.4313)
Not owner occupied	0.0353*** (3.1789)
Low or no documentation	0.0046 (0.9146)
Judicial foreclosure state	0.0256*** (4.8530)
State with redemption law	0.0170*** (3.0925)
Non-recourse state	-0.0026 (-0.5052)
30 to 60 days delinquent at modification	-0.0170** (-2.1800)
90 days delinquent at modification	0.1060*** (18.1344)
<i>Lis pendens</i> at modification	0.1476*** (17.9199)
HAMP modification indicator	-0.0079 (-0.9975)
Percent reduction in principal	-0.0014*** (-4.5463)
Principal increase indicator	0.0194*** (2.9093)
Percent reduction in interest rate	-0.0017*** (-10.7336)
Percent reduction in P&I	-0.0023*** (-12.3182)
Percent Increase in P&I	0.0013*** (4.0230)
Originated 2004	0.0095 (0.6456)
Originated 2005	0.0165

Table 2 (continued)

All modifications	60+ days delinquent within 12 months
	(1.2427)
Originated 2006	0.0321** (2.4315)
Originated 2007	0.0489*** (3.4342)
First modified in 2009	-0.0737*** (-8.7590)
First modified in 2010	-0.1280*** (-12.5243)
First modified in 2011	-0.1811*** (-17.6658)
First modified in 2012	-0.2013*** (-17.2642)
First modified in 2013	-0.3572*** (-23.5345)
CLTV 80 to 89 %	0.0038 (0.4244)
CLTV 90 to 94 %	0.0005 (0.0472)
CLTV 95 to 99 %	0.0076 (0.6955)
CLTV 100 to 124 %	0.0219*** (2.7271)
CLTV 125 to 149 %	0.0396*** (4.2387)
CLTV 150 % and Above	0.0518*** (5.1732)
Year on year change in HPI	-0.0033*** (-10.0126)
Unemployment rate	-0.0144*** (-8.7692)
Log-likelihood	20863.829
Chi-Sq	7740.34
Borrowers	37,027

Probit model for 12 month re-default. Coefficients are average marginal effects. Z-statistics in parentheses. Sample is CoreLogic Loan Performance data on subprime and alt-a mortgages originated from January 1, 2000 to January 1, 2008 and modified after January 1, 2008. Mortgage servicer fixed-effects are included in the model, but coefficients are omitted due to data license agreement

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Other characteristics that appear to contribute to the probability of re-default within 12 months of a modification include the FICO score at loan origination, the year of origination and the year of modification, and the CLTV. FICO scores from origination, which may have been years in the past, do a remarkable job of predicting loan performance, as those with FICO scores above 720 at origination are 23 percentage points, or 59 %, less likely to re-default within 12 months of a modification. CLTV is also strongly predictive of re-default, with those having a CLTV in excess of 150 % being 5 percentage points, or 17 %, more likely to re-default than those with a CLTV below 80 %.

Turning now to our proportional hazard model, we examine a wider range of post-modification loan outcomes. We begin our analysis of post-modification performance with the full sample of modified loans. Table 3 presents the results of the multinomial logit model, where the coefficients are reported as relative risk ratios with the reference outcome being current or 30 days delinquent. In the first column, we report estimates for the outcome being 60 plus days delinquent, followed by the loan being re-modified, entering foreclosure, ending in a foreclosure sale or REO, and short payoff in the final column.

Having a junior lien on the property at the time of modification is among the largest contributors to the mortgage experiencing an adverse outcome. Loans with junior liens have a 27 % higher relative risk of being 60 plus days delinquent, entering foreclosure, or ending in a foreclosure sale or REO. They are also 11 % more likely to require a re-modification, 27 % more likely to enter foreclosure, and 35 % more likely to terminate in a foreclosure sale or REO.

Even after a loan modification, the borrower's FICO score at the time of mortgage origination remains a strong predictor of subsequent mortgage outcomes. Borrowers with FICO scores below 580 at origination are used as the reference category in the model. The higher the origination FICO score, the less likely the loan is to re-default, enter foreclosure, require re-modification, or enter one of the terminal outcomes. For example, borrowers with FICO scores between 580 and 649 have a 22 % lower relative risk of being 60 plus days delinquent, followed by those with a FICO between 650 and 719, who have a 46 % lower relative risk, and then those with a FICO over 720, who have a nearly 70 % lower relative risk of being delinquent. The effect is similarly pronounced for the foreclosure filing or foreclosure sale/REO outcomes—borrowers with FICO scores of 720 or above at origination have a 57 % lower relative risk of foreclosure filing and a 43 % lower relative risk of foreclosure sale/REO.

State-level mortgage laws also play a role in determining re-default following a modification, as loans in states with judicial foreclosure have a 4 % higher relative risk of being 60 plus days delinquent than states without judicial foreclosure. Judicial foreclosure states also have a 158 % higher risk of being in the foreclosure process, but only a 16 % higher risk of foreclosure sale/REO. Conversely, mortgages made in states with redemption laws, or where mortgages are non-recourse loans, have a 5 % and 15 % lower relative risk of being 60 plus days delinquent, respectively. Borrowers in non-recourse states are substantially less likely to experience a foreclosure sale/REO, with a 26 % lower relative risk.

The modification terms affect the post-modification chances of re-default in ways that are consistent with our expectations. Reductions in principal balance, interest rate, and P&I all lower the risk of being 60 plus days delinquent, with a 1 % reduction in any

Table 3 Determinants of mortgage default post modification

All modifications	60+ days delinquent	Modification	Foreclosure filing	REO/ foreclosure Sale	Short pay off
Junior lien	1.2733*** (44.9547)	1.1150*** (9.5839)	1.2723*** (34.6548)	1.3459*** (6.1347)	1.1281* (1.8369)
Loan used for purchase	1.2159*** (36.8474)	1.0438*** (3.7812)	1.3071*** (39.2300)	1.4688*** (8.0780)	1.4738*** (5.9692)
FICO at origination 580 to 649	0.7848*** (-38.1109)	0.8934*** (-7.9138)	0.8385*** (-21.0595)	0.8622** (-2.4673)	0.8373** (-2.0873)
FICO at origination 650 to 719	0.5410*** (-78.6858)	0.7836*** (-14.6813)	0.6537*** (-42.1766)	0.7441*** (-4.1235)	0.8378* (-1.8095)
FICO at origination 720 and above	0.3378*** (-94.0195)	0.7152*** (-15.4874)	0.4266*** (-57.7733)	0.5712*** (-5.5750)	0.8112* (-1.6845)
Not owner occupied	1.0106 (0.8250)	0.9582* (-1.6727)	1.3679*** (21.3709)	2.1275*** (8.9369)	1.8103*** (5.1218)
Low or no documentation	0.9878** (-2.3411)	1.0224** (2.0058)	1.2000*** (27.1400)	1.0175 (0.3623)	0.8296*** (-2.8198)
Judicial foreclosure state	1.0422*** (7.6312)	1.0557*** (4.6364)	2.5766*** (133.7266)	1.1558*** (2.9102)	0.8627** (-2.0377)
State with redemption Law	0.9459*** (-10.1165)	1.0852*** (6.8926)	0.9335*** (-9.2896)	1.0720 (1.3807)	1.2980*** (3.7563)
Non-recourse state	0.8496*** (-31.7401)	0.9907 (-0.8406)	1.0331*** (4.7742)	0.7376*** (-6.4792)	0.7393*** (-4.6375)
30 to 60 days delinquent at mod	0.8506*** (-20.4122)	1.0264 (1.5383)	0.6662*** (-37.9351)	0.7091*** (-4.6998)	0.8609* (-1.6587)
90 days delinquent at mod	1.5013*** (67.1580)	1.1951*** (13.8839)	1.3060*** (34.0016)	1.1806*** (3.0398)	1.0781 (1.0346)
<i>Lis pendens</i> at modification	1.5621*** (50.5895)	1.2345*** (11.5045)	2.1958*** (77.4103)	1.6905*** (7.3833)	0.9957 (-0.0376)
HAMP modification Indicator	0.8341*** (-20.3934)	0.9409*** (-3.6840)	0.7914*** (-19.6933)	0.7818*** (-2.7566)	0.6662*** (-3.4606)
Percent reduction in principal	0.9907*** (-25.5084)	1.0109*** (18.8404)	0.9852*** (-27.8904)	0.9872*** (-2.8212)	0.9945 (-1.2255)
Principal increase indicator	1.2094*** (28.1732)	0.7299*** (-23.2988)	1.2489*** (25.2877)	1.1880*** (2.7894)	0.9078 (-1.2770)
Percent reduction in interest rate	0.9916*** (-56.1733)	0.9950*** (-15.1709)	0.9929*** (-37.6971)	0.9937*** (-4.8288)	0.9916*** (-4.8137)
Percent reduction in P&I	0.9914*** (-44.1244)	0.9994 (-1.5710)	0.9862*** (-55.5205)	0.9823*** (-10.0025)	0.9862*** (-5.8604)
Percent increase in P&I	1.0045*** (14.3399)	1.0088*** (13.6317)	1.0020*** (5.0461)	0.9957 (-1.5278)	1.0025 (0.7809)
Originated 2004	1.1481*** (8.8870)	1.0119 (0.3647)	0.9762 (-1.1664)	0.7048** (-2.4506)	1.2120 (0.8113)

Table 3 (continued)

All modifications	60+ days delinquent	Modification	Foreclosure filing	REO/foreclosure Sale	Short pay off
Originated 2005	1.1088*** (7.2592)	0.9463* (-1.8733)	0.9831 (-0.9170)	0.7445** (-2.3776)	1.3131 (1.2376)
Originated 2006	1.1784*** (11.6467)	0.9635 (-1.2746)	1.0621*** (3.2825)	0.7274*** (-2.5834)	1.2920 (1.1682)
Originated 2007	1.3672*** (20.5445)	1.0123 (0.3895)	1.1482*** (6.9617)	0.6287*** (-3.3706)	1.3245 (1.2147)
First modified in 2009	0.6957*** (-59.5842)	0.9107*** (-5.9199)	0.7605*** (-34.9966)	0.7376*** (-5.5318)	0.7112*** (-4.3944)
First modified in 2010	0.5140*** (-87.8916)	0.7017*** (-20.2591)	0.6536*** (-42.3184)	0.6877*** (-5.1038)	0.7741** (-2.5694)
First modified in 2011	0.4580*** (-68.9384)	0.5377*** (-30.5340)	0.7023*** (-22.7338)	0.6894*** (-3.1181)	0.9344 (-0.4648)
First modified in 2012	0.4157*** (-47.9201)	0.4299*** (-32.1937)	0.5889*** (-18.3581)	0.4662*** (-2.9972)	0.7683 (-1.0258)
First modified in 2013	0.2637*** (-34.7610)	0.5833*** (-16.9116)	0.1885*** (-17.7689)		0.8902 (-0.2651)
CLTV 80 to 89%	1.0997*** (8.9568)	1.2090*** (9.1192)	1.1745*** (10.1971)	0.9662 (-0.2344)	0.8112 (-1.2821)
CLTV 90 to 94%	1.1333*** (10.2082)	1.2079*** (7.6177)	1.3592*** (17.4063)	1.5842*** (3.0610)	0.8945 (-0.5876)
CLTV 95 to 99%	1.1525*** (11.6426)	1.2532*** (9.0919)	1.4145*** (19.9955)	1.7309*** (3.7243)	0.7382 (-1.4955)
CLTV 100 to 124%	1.3217*** (30.7907)	1.4081*** (18.6866)	1.6865*** (39.8238)	2.7290*** (8.9984)	1.2835* (1.9305)
CLTV 125 to 149%	1.5117*** (41.3086)	1.6120*** (22.9354)	2.1482*** (54.4275)	4.0728*** (12.0104)	2.2934*** (6.1622)
CLTV 150% and above	1.7614*** (54.6232)	1.8950*** (29.2492)	3.1539*** (80.3222)	9.9549*** (19.8489)	5.6810*** (13.1472)
Year on year change in HPI	0.9940*** (-17.7814)	1.0028*** (4.0056)	0.9813*** (-41.4944)	0.9874*** (-4.1502)	0.9981 (-0.4622)
Unemployment rate	1.0414*** (26.8725)	0.9170*** (-28.1434)	1.0731*** (32.6121)	0.9642** (-2.4733)	0.9561** (-2.2265)
Log-likelihood	-1137702.7				
Chi-Sq	316459.25				
Observations	1,353,338				
Borrowers	37,027				

Competing risk models with relative risk ratios reported. t-statistics in parentheses. Sample is CoreLogic Loan Performance data on subprime and alt-a mortgages originated from January 1, 2000 to January 1, 2008 and modified after January 1, 2008. Mortgage servicer fixed-effects are included in the model, but coefficients are omitted due to data license agreement. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4 Determinants of mortgage default post modification

Non-HAMP modifications	60+ days delinquent	Modification	Foreclosure filing	REO/ Foreclosure sale	Short pay off
Junior lien	1.2722*** (41.9659)	1.1124*** (8.2996)	1.2594*** (31.3031)	1.3133*** (5.3759)	1.1135 (1.5593)
Loan used for purchase	1.1960*** (31.7350)	1.0274** (2.1326)	1.2926*** (35.5934)	1.4716*** (7.7811)	1.4356*** (5.3158)
FICO at origination 580 to 649	0.7919*** (-35.0749)	0.9109*** (-6.0823)	0.8509*** (-18.5257)	0.8597** (-2.4449)	0.8680 (-1.6128)
FICO at origination 650 to 719	0.5519*** (-71.7569)	0.8046*** (-11.8361)	0.6617*** (-38.8341)	0.7540*** (-3.8002)	0.8471 (-1.6242)
FICO at origination 720 and above	0.3519*** (-83.4536)	0.7207*** (-13.0672)	0.4393*** (-51.9767)	0.5788*** (-5.1397)	0.9019 (-0.7968)
Not owner occupied	0.9966 (-0.2575)	0.9461** (-2.0132)	1.3513*** (19.9094)	2.0542*** (8.2309)	1.8247*** (5.0931)
Low or no documentation	1.0096* (1.7061)	1.0296** (2.3728)	1.2471*** (31.2218)	1.0498 (0.9749)	0.8347*** (-2.6029)
Judicial foreclosure state	1.0415*** (7.1112)	1.0668*** (4.9975)	2.6010*** (128.8797)	1.1973*** (3.4955)	0.8630* (-1.9599)
State with redemption law	0.9459*** (-9.5693)	1.1487*** (10.5981)	0.9313*** (-9.1480)	1.0607 (1.1293)	1.3017*** (3.6618)
Non-recourse state	0.8667*** (-26.3498)	1.0327*** (2.5861)	1.0501*** (6.8252)	0.7434*** (-6.0771)	0.7480*** (-4.2868)
30 to 60 days delinquent at mod	0.8711*** (-16.9756)	1.0511*** (2.7606)	0.6906*** (-33.8067)	0.7253*** (-4.3171)	0.8510* (-1.7504)
90 days delinquent at mod	1.5439*** (68.2650)	1.2553*** (15.9497)	1.3614*** (37.4361)	1.2212*** (3.5274)	1.0677 (0.8675)
<i>Lis pendens</i> at modification	1.5786*** (47.8949)	1.3016*** (12.6952)	2.3141*** (77.2253)	1.6851*** (6.9095)	1.0146 (0.1184)
Percent reduction in principal	0.9873*** (-30.8919)	1.0159*** (22.8105)	0.9807*** (-31.9079)	0.9800*** (-3.7905)	0.9936 (-1.3504)
Principal increase indicator	1.1997*** (25.4108)	0.7220*** (-21.4975)	1.2490*** (23.9162)	1.1681** (2.4235)	0.8977 (-1.3746)
Percent reduction in interest rate	0.9899*** (-62.8272)	0.9986*** (-3.8173)	0.9909*** (-44.9936)	0.9916*** (-6.0057)	0.9887*** (-6.0427)
Percent reduction in P&I	0.9919*** (-38.1220)	0.9989** (-2.3086)	0.9860*** (-51.6676)	0.9825*** (-9.1789)	0.9865*** (-5.3259)
Percent increase in P&I	1.0041*** (12.4262)	1.0096*** (13.6109)	1.0010** (2.4406)	0.9953 (-1.5856)	1.0011 (0.3116)
Originated 2004	1.1733*** (9.8864)	1.0379 (1.0516)	0.9912 (-0.4093)	0.7577* (-1.8624)	1.2189 (0.8163)
Originated 2005	1.1373*** (8.6818)	0.9968 (-0.0993)	1.0230 (1.1770)	0.8101 (-1.6131)	1.3033 (1.1748)

Table 4 (continued)

Non-HAMP modifications	60+ days delinquent	Modification	Foreclosure filing	REO/Foreclosure sale	Short pay off
Originated 2006	1.2277*** (13.9607)	1.0137 (0.4298)	1.1121*** (5.5522)	0.7825* (-1.8893)	1.3787 (1.4303)
Originated 2007	1.4490*** (23.1838)	1.0794** (2.2166)	1.2039*** (8.9034)	0.6611*** (-2.8319)	1.3900 (1.3828)
First modified in 2009	0.7002*** (-57.4827)	0.9450*** (-3.5209)	0.7722*** (-32.5178)	0.7438*** (-5.2972)	0.7067*** (-4.4100)
First modified in 2010	0.4941*** (-87.9564)	0.7252*** (-17.3779)	0.6274*** (-43.9487)	0.6777*** (-5.0708)	0.7519*** (-2.7404)
First modified in 2011	0.4602*** (-61.2545)	0.5192*** (-28.1316)	0.7342*** (-18.0242)	0.7994* (-1.7643)	1.0223 (0.1437)
First modified in 2012	0.4078*** (-42.1570)	0.3794*** (-30.4024)	0.5582*** (-17.1404)	0.3994*** (-2.8973)	0.8639 (-0.5365)
First modified in 2013	0.2430*** (-31.3391)	0.5534*** (-15.5741)	0.1767*** (-15.9837)		0.9228 (-0.1686)
CLTV 80 to 89%	1.0913*** (7.8294)	1.1076*** (4.5274)	1.1803*** (10.0180)	0.9633 (-0.2428)	0.8307 (-1.1082)
CLTV 90 to 94%	1.1200*** (8.7923)	1.0574** (2.0562)	1.3528*** (16.3322)	1.6300*** (3.1282)	0.9426 (-0.3079)
CLTV 95 to 99%	1.1391*** (10.1602)	1.1070*** (3.7557)	1.4202*** (19.3251)	1.6756*** (3.3213)	0.7082 (-1.6280)
CLTV 100 to 124%	1.3057*** (27.8860)	1.2198*** (9.9254)	1.6880*** (37.8945)	2.7884*** (8.7554)	1.2639* (1.7466)
CLTV 125 to 149%	1.4722*** (36.4910)	1.3880*** (14.2415)	2.1086*** (50.3475)	4.0417*** (11.3669)	2.3198*** (6.0441)
CLTV 150% and above	1.6945*** (47.8820)	1.6195*** (19.6891)	3.0614*** (74.0466)	9.9146*** (18.8599)	5.3354*** (12.1807)
Year on year change in HPI	0.9943*** (-15.8587)	1.0014* (1.8069)	0.9811*** (-39.7647)	0.9860*** (-4.4260)	0.9953 (-1.1104)
Unemployment rate	1.0544*** (33.6480)	0.8889*** (-35.8583)	1.0879*** (37.5526)	0.9818 (-1.2106)	0.9665* (-1.6489)
Log-likelihood	-1256731.9				
Chi-Sq	277739.38				
Observations	1,383,936				
Borrowers	28,652				

Competing risk models with relative risk ratios reported. t-statistics in parentheses. Sample is CoreLogic Loan Performance data on subprime and alt-a mortgages originated from January 1, 2000 to January 1, 2008 and receiving a proprietary modification after January 1, 2008. Mortgage servicer fixed-effects are included in the model, but coefficients are omitted due to data license agreement

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

of these terms reducing the risk of being delinquent by 0.9, 0.8, and 0.9 %, respectively. Conditional on receiving a principal reduction, the average mortgage balance reduction was 25 % (Table 1), suggesting that a typical loan that received a principal reduction was 23 % less likely to be 60 plus days delinquent. As our model controls for any changes in the CLTV resulting from the principal reduction, this estimate captures only part of the total effect of a principal reduction on subsequent loan performance. For those who received an interest rate reduction, the average change was 54 %, while for those receiving a P&I reduction the average was 51 %; thus, our coefficient estimates imply typical reductions in the relative risk of being 60 plus days delinquent of 45 % and 44 %, respectively.

Turning to the effect of mortgage modification terms on the subsequent risk of entering foreclosure or terminating in a foreclosure sale/REO, the effect of principal reductions and P&I reductions becomes even more pronounced. A 1 % reduction in principal is estimated to reduce the likelihood of receiving a foreclosure filing by 1.5 % and terminating in a foreclosure sale/REO by 1.3 %. A 1 % reduction in P&I yields a 1.4 % reduction in the likelihood of receiving a foreclosure filing, a 1.8 % reduction in the likelihood of terminating in a foreclosure sale/REO, and a 1.4 % reduction in the likelihood of a short sale. Following Chen et al. (2014) we disaggregated the percent reduction in P&I into categories for the ranges 10 to 30 %, 31 to 40 %, and 40 plus percent to examine whether reductions in P&I have a non-linear effect on mortgage performance, and in particular whether loans receiving substantial P&I reductions are actually more likely to default. In results not shown, we find no evidence that P&I reductions of 40 % or more are associated with an increase in re-default and foreclosure. In fact, the benefits of P&I reductions in terms of lower re-default and foreclosure continue to increase in proportion to the size of the P&I reduction.

As previously mentioned, many of the early mortgage modifications actually resulted in increases in principal balances and the monthly P&I, as accumulated interest and fees were capitalized. The ineffectiveness of this approach is clearly demonstrated in our results, as modifications that resulted in any principal balance increase were 21 % more likely to be 60 plus days delinquent, 25 % more likely to result in a foreclosure filing, and 19 % more likely to terminate in a foreclosure sale/REO. Modifications that included an increase in P&I were 0.5 % more likely to be 60 plus days delinquent for each 1 % increase in P&I, and 0.2 % more likely to result in a foreclosure filing for each 1 % increase in P&I. They were also far more likely to end up requiring a subsequent re-modification, with a 0.9 % higher relative risk for each 1 % increase in P&I. For those loans that had an increase in P&I, the average was 13 %, implying that the average modification that increased P&I was 6.5 % more likely to be 60 plus days delinquent, 2.6 % more likely to be in foreclosure, and 12 % more likely to require re-modification.

Even conditional on the actual modification terms, modifications done through the HAMP program appear to be particularly effective. HAMP modifications have a 17 % lower relative risk of being 60 plus days delinquent, a 21 % lower relative risk of experiencing a foreclosure filing, a 22 % lower relative risk of terminating in a foreclosure sale/REO, and a 34 % lower relative risk of ending in a short sale. This finding is consistent with Agarwal et al. (2012) who find HAMP modifications to be more aggressive than non-HAMP modifications and result in better mortgage outcomes for the borrowers.

The CLTV following a modification is by far the largest determinant of subsequent mortgage outcomes, with the likelihood of default, foreclosure, and REO increasing substantially as the CLTV increases. The CLTV is constructed by dividing the current total value of the first lien mortgage and any junior liens by CoreLogic's AVM estimate for the property value. Relative to the reference category of a CLTV below 80 %, a borrower with a CLTV ratio between 80 and 89 % has a 10 % higher relative risk of being 60 plus days delinquent, a 21 % higher risk of requiring a re-modification, and a 17 % higher relative risk of entering foreclosure. However, for borrowers with a CLTV between 80 and 89 % there is no significant difference in the likelihood of the mortgage terminating in a foreclosure sale/REO or short sale compared with those borrowers with a CLTV below 80 %.

The likelihood of an adverse outcome consistently increases with each higher category of CLTV included in the model, with a notable jump in coefficient magnitude once CLTV enters the 90 to 94 % category, and again once CLTV enters the 100 to 124 % category. Borrowers with a CLTV of between 100 and 124 % are 32 % more likely to be 60 plus days delinquent, 69 % more likely to enter foreclosure, 173 % more likely to terminate in a foreclosure sale/REO, and 28 % more likely to terminate in a short sale. They are also 41 % more likely to require a re-modification of their mortgage. Finally, at the extreme, borrowers with a CLTV of 150 % or more are 76 % more likely to be 60 plus days delinquent, 215 % more likely to enter foreclosure, 895 % more likely to terminate in a foreclosure sale/REO, and 468 % more likely to terminate in a short sale.

While these values for the effect of CLTV on adverse outcomes may appear extreme, they are consistent with Bhutta et al. (2010) who find that borrowers with a CLTV of 150 % or more are over 10 times more likely to default than borrowers with a CLTV of around 100 %. This result is driven in part by their finding that when home equity falls below negative 62 % (CLTV greater than 162 %) borrowers are far more likely to strategically default on their loans (stop paying the mortgage even if they are able to make the monthly payment). Guiso et al. (2013) also find that borrowers are substantially more likely to report a willingness to strategically default when the absolute value of negative equity is \$100,000 or greater. However, Gerardi et al. (2013a) suggest that strategic default is less prevalent than previously estimated, as only 14 % of borrowers with negative equity who default in the Panel Study of Income Dynamics (PSID) have sufficient assets to make 1 month's mortgage payment. Borrowers who have substantial negative equity may also be those who experience the most severe (unobserved) negative financial shocks.

As mentioned above, the aggregate effect of a principal reduction on subsequent loan performance is a combination of the share of principal reduced and the change in the CLTV. A principal reduction also mechanically reduces the P&I, assuming the loan amortization period isn't shortened. Given the large magnitude of the coefficients found for CLTV, as well as the magnitude of the coefficients on both the principal reduction and P&I variables, principal reductions would appear to be an extremely effective modification strategy, particular for those borrowers with CLTVs in excess of 100 %.

As we find that modifications done under the HAMP are significantly more effective than proprietary mortgage modifications, we next split our sample into non-HAMP and HAMP modifications and re-run our analysis. The results for the non-HAMP loans are presented in Table 4, while those for the HAMP loans are presented in Table 5. For the non-HAMP loans, we see little change in any of the coefficient magnitudes or levels of

Table 5 Determinants of mortgage default post modification

HAMP modifications	60+ Days delinquent	Modification	Foreclosure filing	REO/ Foreclosure sale	Short pay off
Junior lien	1.2769*** (14.8055)	1.0242 (0.8521)	1.4534*** (16.3867)	1.9502*** (3.8747)	1.1773 (0.7110)
Loan used for purchase	1.3223*** (16.7001)	1.1606*** (5.1026)	1.3555*** (13.1568)	1.3244 (1.5854)	1.6920** (2.2257)
FICO at origination 580 to 649	0.7298*** (-13.7789)	0.7737*** (-5.8839)	0.7103*** (-10.8122)	0.9153 (-0.3267)	0.4686** (-2.0791)
FICO at origination 650 to 719	0.4973*** (-27.6850)	0.6020*** (-10.8470)	0.6437*** (-12.8334)	0.8023 (-0.7562)	0.6760 (-1.0786)
FICO at origination 720 and above	0.2973*** (-36.3609)	0.5416*** (-11.2618)	0.4008*** (-19.9360)	0.6435 (-1.2523)	0.3876** (-2.0673)
Not owner occupied	1.0812 (1.4584)	1.0448 (0.5465)	1.2044*** (2.6301)	2.5018** (2.4583)	1.0964 (0.1265)
Low or no documentation	0.9013*** (-6.3275)	0.8925*** (-3.9006)	0.9316*** (-3.1042)	0.8320 (-1.0222)	0.9162 (-0.3608)
Judicial foreclosure state	0.9977 (-0.1295)	1.0397 (1.2411)	2.1104*** (29.2578)	0.7697 (-1.2912)	0.8402 (-0.5791)
State with redemption law	0.9731 (-1.4761)	0.9947 (-0.1616)	1.0135 (0.5063)	1.4994* (1.9547)	1.0943 (0.3245)
Non-recourse state	0.7295*** (-18.7155)	0.8826*** (-4.1199)	0.8681*** (-6.0095)	0.6747** (-2.1106)	0.7933 (-0.8999)
30 to 60 days delinquent at mod	0.5009*** (-15.6834)	0.8321*** (-3.2659)	0.3032*** (-17.4861)	0.3327** (-2.2604)	1.0002 (0.0005)
90 days delinquent at mod	1.2457*** (10.1226)	0.9642 (-1.0616)	0.9435** (-2.0399)	0.8234 (-0.8828)	1.2067 (0.5803)
<i>Lis pendens</i> at modification	1.5941*** (17.5472)	0.8803*** (-2.7671)	1.5821*** (13.9688)	1.7137** (2.2060)	1.0171 (0.0395)
Percent reduction in principal	1.0097*** (11.0946)	1.0077*** (6.4157)	1.0052*** (4.0510)	1.0177* (1.6524)	1.0147 (0.9976)
Principal increase indicator	1.2142*** (8.6353)	0.9707 (-0.8403)	1.0514* (1.6519)	1.1770 (0.6555)	1.1096 (0.3132)
Percent reduction in interest rate	1.0087*** (16.9568)	0.9598*** (-40.3141)	1.0119*** (16.7990)	1.0123** (2.5421)	1.0250*** (3.0605)
Percent reduction in P&I	0.9849*** (-28.0106)	1.0011 (1.1856)	0.9852*** (-20.0788)	0.9779*** (-4.0891)	0.9796*** (-2.7613)
Originated 2004	0.8561*** (-2.7036)	0.7692*** (-2.7963)	0.9018 (-1.3250)	0.2825** (-2.1101)	1.0584 (0.0485)
Originated 2005	0.8320*** (-3.5959)	0.6713*** (-4.7178)	0.6598*** (-6.0229)	0.2800*** (-2.8840)	1.4304 (0.3442)
Originated 2006	0.8159*** (-4.0284)	0.7572*** (-3.3410)	0.7442*** (-4.3409)	0.3788** (-2.2817)	0.7107 (-0.3273)

Table 5 (continued)

HAMP modifications	60+ Days delinquent	Modification	Foreclosure filing	REO/ Foreclosure sale	Short pay off
Originated 2007	0.8401*** (-3.3311)	0.8437** (-1.9668)	0.8083*** (-3.0302)	0.3576** (-2.2789)	0.8860 (-0.1146)
First modified in 2010	0.9903 (-0.4296)	0.8569*** (-3.1601)	1.2433*** (6.8587)	0.8930 (-0.5029)	1.3761 (0.9907)
First modified in 2011	0.9206*** (-2.7779)	0.6803*** (-7.3475)	1.2960*** (5.9507)	0.6111 (-1.3932)	1.6019 (0.9976)
First modified in 2012	0.8792*** (-2.9541)	0.6438*** (-7.1034)	1.3522*** (4.4854)	0.7962 (-0.4231)	0.5658 (-0.4917)
First modified in 2013	0.7286*** (-3.9772)	0.6224*** (-6.0387)	0.5815*** (-2.8068)		4.2347 (1.1606)
CLTV 80 to 89%	1.2800*** (6.8232)	1.5546*** (7.5289)	1.1718*** (2.8266)	1.3032 (0.5221)	0.2791 (-1.1701)
CLTV 90 to 94%	1.3592*** (7.3005)	1.9505*** (9.9623)	1.5196*** (6.8122)	0.9390 (-0.0936)	0.0000 (.)
CLTV 95 to 99%	1.4107*** (8.2372)	1.8112*** (8.6379)	1.4033*** (5.3437)	3.0099** (2.2921)	1.3795 (0.4395)
CLTV 100 to 124%	1.5661*** (14.7574)	2.2271*** (16.2408)	1.7789*** (12.8357)	2.1400* (1.8777)	1.3855 (0.6100)
CLTV 125 to 149 %	2.0071*** (21.2951)	2.4952*** (16.8353)	2.7280*** (21.2819)	4.7492*** (3.8129)	1.8312 (1.0619)
CLTV 150 % and above	2.6373*** (28.8969)	2.6027*** (17.2630)	4.6177*** (32.0381)	11.2310*** (5.9585)	9.3693*** (4.2273)
Year on year change in HPI	0.9879*** (-11.0115)	0.9939*** (-2.7886)	0.9791*** (-13.5891)	0.9994 (-0.0537)	1.0076 (0.5034)
Unemployment rate	0.9497*** (-8.3987)	0.9220*** (-7.9595)	0.9651*** (-3.7764)	0.7572*** (-4.1921)	0.9993 (-0.0073)
Log-Likelihood	-127453.67				
Chi-Sq	53445.08				
Observations	239,626				
Borrowers	8,375				

Competing risk models with relative risk ratios reported. t-statistics in parentheses. Sample is CoreLogic Loan Performance data on subprime and alt-a mortgages originated from January 1, 2000 to January 1, 2008 and receiving a HAMP modification after March 2009. Mortgage servicer fixed-effects are included in the model, but coefficients are omitted due to data license agreement

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

statistical significance from the full sample, which is relatively unsurprising given that the HAMP loans make up only 22 % of the full sample.

In contrast, the results for the HAMP loans reported in Table 5 are notably different than those for the full sample. Here, reductions in principal and the interest rate are

estimated to modestly *increase* the relative risk of being 60 plus days delinquent, entering foreclosure, or terminating with a foreclosure sale/REO. This result is likely driven by the waterfall nature of HAMP modifications, where larger reductions in the interest rate or principal balance are indicative of a particularly distressed borrower. However, the coefficient on the percent reduction in P&I remains consistent with what we would expect, as a 1 % reduction in P&I is estimated to reduce the relative risk of being 60 plus days delinquent by 1.5 %, entering foreclosure by 1.5 %, terminating in a foreclosure sale/REO by 2.3 %, and terminating in a short sale by 2 %.

For the sample of HAMP loans, the magnitude of the coefficients on the CLTV categories increases substantially relative to the non-HAMP loans, particularly at the upper-end of the CLTV distribution. At every level of CLTV in excess of 80 %, we see substantial increases in the relative risk of the adverse outcomes. Again, there is a particularly pronounced jump in the effect of CLTVs in excess of 100 %: Those with a CLTV of 100 to 124 % are now 57 % more likely to be 60 plus days delinquent, 78 % more likely to enter foreclosure, and 114 % more likely to terminate in a foreclosure sale/REO. At a CLTV of 150 % or more, the mortgage is 164 % more likely to be 60 plus days delinquent, 362 % more likely to enter foreclosure, 1000 % more likely to terminate in a foreclosure sale/REO, and 837 % more likely to terminate in a short sale. Overall, these results suggest that HAMP modifications that reduce principal would be most effective at reducing subsequent default and foreclosure.

Conclusion

We use both a probit model and a discrete time proportional hazard framework with competing risks to analyze how the parameters of mortgage modifications affect the post-modification loan performance. Using a rich dataset that provides information on modification parameters, second liens, and current property values our estimates suggest the completely intuitive conclusion that modifications that improve the terms of the loan for the borrower—such as reductions in the interest rate, the monthly P&I, or the loan's principal balance—reduce the likelihood that the borrower re-defaults and enters foreclosure. Conversely, modifications that capitalize accrued interest and fees, resulting in an increase in the mortgage balance, or that increase the monthly P&I are particularly prone to re-default and end in foreclosure. Principal reductions are particularly effective, as they appear to independently affect subsequent mortgage performance, as well as affect subsequent performance through a reduction in the LTV ratio and the P&I. HAMP modifications also appear to perform substantially better than non-HAMP modifications, independent of the terms of the actual modification.

Mortgages with CLTV ratios in excess of 100 % following a modification, and especially those with CLTV ratios above 150 %, are far more likely to re-default than those with some equity. Thus, when implementing a principal reduction, it would appear reasonable for servicers to target reductions in the total of outstanding loan balances on the property below one of these key CLTV thresholds. However, a broad-based policy of principal reduction may introduce moral hazard into the mortgage market, resulting in borrowers strategically defaulting to obtain a modification and reduce their principal balance (Foote et al. 2008). Applying the learnings from the previous literature on negative equity and strategic default to target only borrowers experiencing both high

negative equity and an income shock may reduce moral hazard and yield more cost-effective principal reductions (Bhutta et al. 2010; Foote et al. 2008).

While principal reductions are clearly the most effective type of mortgage modification, as measured by subsequent loan performance, they may not necessarily be the most cost-effective for the investor on a net present value basis. Further analysis of the costs to investors of the various types of modifications relative to their effect on loan performance is necessary to make the final determination. However, our results provide an important input into the calculation of modification costs versus benefits.

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