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UNIVERSITY OF CALIFORNIA, SAN DIEGO

Three Essays in Housing Finance

A dissertation submitted in partial satisfaction of the
requirements for the degree
Doctor of Philosophy

in

Economics

by

Therese C. Scharlemann

Committee in charge:

Professor Richard Carson, Chair
Professor Julie Cullen
Professor Josh Graff Zivin
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Professor Michelle White

2015

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The dissertation of Therese C. Scharlemann is approved, and
it is acceptable in quality and form for publication on micro-
film and electronically:

Chair

University of California, San Diego

2015

DEDICATION

To my parents, for their patience, love, and support through many highs and lows. No kid was ever luckier. And to Matt, the love of my life, for introducing me to the gravity model.

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Chapter 3, in full, is a reprint of the material in Holden, Steve, Austin Kelly, Douglas A. McManus, Therese Scharlemann, Ryan Singer, and John Worth, "The HAMP NPV Model: Development and Early Performance", *Real Estate Economics*, 314, 2012.

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ABSTRACT OF THE DISSERTATION

Three Essays in Housing Finance

by

Therese C. Scharlemann

Doctor of Philosophy in Economics

University of California, San Diego, 2015

Professor Richard Carson, Chair

This dissertation presents three empirical papers studying the economics of mortgage modifications through the lens of a large, government-sponsored mortgage modification program, the Home Affordable Modification Program. The first paper tests whether borrowers' default probability is sensitive to the wealth transfer embodied in their mortgage modification independent of the liquidity benefit of the modification. The Home Affordable Modification stipulates that mortgage servicers use a specific formula to lower borrowers' payments to 31 percent of their gross monthly income. To estimate the causal impact of the wealth transfer on mortgage default, I use a regression kink design (RKD) that exploits transition points in the mortgage modification formula,

where the method used to achieve the marginal dollar of payment reduction changes from rate reduction to term extension and from term extension to principal forbearance (a balloon payment held at a zero percent rate). These transition points create quasi-experimental variation in the wealth transfer embodied in the borrowers' modification. I find that borrowers would have defaulted at a 33 percent higher rate had the modification formula not involved rate reduction and had instead relied on term extension and principal forbearance, which transfer little value to borrowers. The second paper (joint with Stephen H. Shore) evaluates the extent to which borrowers' default rate is affected by principal forgiveness, arguably the most salient method of transferring wealth to borrowers. The formula for principal forgiveness is a kinked function of the borrower's original loan-to-value (LTV) ratio and debt-to-income (DTI) ratio. Eligible borrowers receive the minimum amount of principal forgiveness sufficient to reduce the monthly payment to the payment target (31 percent of gross monthly income) or to reduce the balance to a servicer-specific share of the home's current value (typically 115 percent or 100 percent). We exploit the quasi-experimental variation in principal forgiveness generated by this kink using an RKD specification to estimate the causal effect of principal forgiveness on subsequent borrower default. The quarterly default hazard in the sample was 3.1%. We estimate that it would have been 3.8% absent principal forgiveness, which averaged 28% of the original unpaid balance. My third paper, joint with Steven Holden, Austin Kelly, Douglas McManus, Ryan Singer, and John Worth, discusses the structure of the HAMP's Net Present Value (NPV) model, which is the cashflow model used to assess the economic viability of applicants to the HAMP program.

Chapter 1

The Effect of Wealth Transfers in Mortgage Modification on Default

Abstract

I evaluate the extent to which borrowers' default probability is sensitive to the implied wealth transfer embodied in their mortgage modification using administrative data on Fannie Mae and Freddie Mac mortgages in the Home Affordable Modification Program (HAMP). Kinks in the composition of the mortgage modification among rate reduction, term extension, and principal forbearance create quasi-experimental variation in the terms of the mortgage modification, *ceteris paribus*. These kinks occur at two points: first, where HAMP modification formula requires a transition from rate reduction to term extension to achieve a fixed payment target, and second, where term extension transitions to forbearance. I use a regression kink design (RKD) to evaluate whether changes in the composition of the mortgage modification at these kink points affect the monthly hazard of mortgage default. The first transition implies a large change in the wealth transfer associated with the modification; the effect of the second transition

on the wealth transfer is much smaller.

I find that default is decreasing in the share of the payment reduction comprised of rate reduction. Borrowers' payments were reduced by 37%, on average, using rate reduction alone. I estimate that had term extension or forbearance been used to achieve the same payment reduction, the monthly hazard of default would have been 33% higher. I find that using forbearance rather than term extension to achieve a given payment reduction has no effect on the default probability. Together, these findings imply that borrowers are sensitive to the wealth transfer embodied in their modification to a degree that is both statistically and economically significant.

1.1 Introduction

In the wake of the housing downturn and concurrent widespread mortgage defaults, the federal government introduced the Home Affordable Modification Program (HAMP) to encourage wide use of payment-reducing loan modifications to prevent foreclosure. Though the program has expanded since its introduction, the original - and largest - program subsidizes a specific mortgage modification, which uses a series of prescribed adjustments to the applicant's mortgage terms to reduce the borrower's monthly mortgage payment. In most cases, borrowers emerged with mortgage payments equal to 31 percent of their gross monthly income.

The transparency of the HAMP modification rules provides a unique opportunity to evaluate the sensitivity and awareness of borrowers to the value of the wealth transfer embodied in their mortgage modification. Outside of the HAMP program, the algorithms used for allocating modifications are not transparent, and the structure of the modifications may reflect unobserved characteristics of the borrower, the mortgage servicer, or the mortgage lender, which may be correlated with the subsequent mortgage

performance. The HAMP modifications, in contrast, were calculated using borrower and mortgage characteristics that are observable to the researcher. The uniform structure of the modification therefore minimizes the role of unobservable information in determining the final terms of the modified mortgage.

The general formula for the modification requires servicers to decrement the rate on the applicant's mortgage until the monthly payment, including taxes and insurance, reaches 31 percent of the borrower's pre-tax monthly income. If this payment target cannot be achieved by reducing the rate to 2 percent, the servicer must lengthen the mortgage term until the payment target is met. If a the payment target cannot be achieved by lengthening the term to 480 months, the servicer must forbear principal, i.e., create a zero-interest balloon with payment due at maturity or upon refinance or sale of the home.

The transition points in this formula - where the method of achieving the marginal dollar of payment reduction changes from rate reduction to term extension, and from term extension to principal forbearance - create kinks in the implied value transferred to the borrower through the modification. Variation in both the borrower's pre-modification mortgage terms (rate and amortization term) and in the portion of borrowers' mortgage payments absorbed by taxes and insurance imply that borrowers with the same percentage change in monthly payments may experience different changes in their wealth from the modification. While borrowers' pre-modification interest rates and remaining amortization terms may be correlated with ex post default probabilities, the RKD identification strategy, combined with the multi-dimensional nature of these kinks, allows me to control flexibly for the influence of these factors on default.

I find evidence that borrowers are sensitive to the wealth transfer implied by their mortgage modification, holding constant the liquidity benefit (payment change) associated with their modification. I find that rate reduction is more effective than term

extension at reducing subsequent default rates. On average, borrowers in the group of loans near the first kink received a rate reduction that reduced their payment by an average of 37 percent. The monthly default hazard in this group of loans was 0.07 percent. I estimate that a modification that consisted entirely of term extension and forbearance would see monthly default hazards that were about 33 percent higher, at 0.09 percent. The first cohort of loans - those originated in the second half of 2009 - saw a cumulative default rate of about 40% in the 5 years following modification. I estimate that the cumulative default rate for this cohort would have been about 50% absent rate reduction.

My findings contribute both to our understanding of the pathways through which modifications help avoid foreclosure, and to the literature evaluating the effect of monetary policy on housing markets. The framework used in this paper does not facilitate separate identification of liquidity and wealth effects associated with mortgage modifications, but it does present a previously un-tested pathway through which both refinance and modification programs influence borrower behavior. To my knowledge, this is the first research to examine the value implied by the payment-reducing mortgage modification separately from the liquidity impact and empirically demonstrate borrower sensitivity to this particular feature of the modification.

Several branches of literature speak to the drivers of mortgage default. Both theory (see e.g. (Campbell and Cocco, 2015)) and empirical evidence suggest that borrowers with negative or low home equity are more likely to default than are borrowers with strong equity positions. Borrowers with positive equity can avoid foreclosure by selling their home and satisfying their outstanding mortgage balances and any transaction costs. Borrowers with low or negative equity do not have that flexibility, and negative economic shocks such as job loss, health problems, or divorce are much more likely to result in forced default and subsequent foreclosure for these borrowers. In ad-

dition to being more likely to default in response to economic shocks, negative equity borrowers may default because they do not want to pay a price for their house that is ex post too high. Defaulting may improve the household balance sheet. (Although some states allow lenders to pursue borrowers for the full balance of their loan, in practice, this option is rarely exercised.)

The degree to which mortgage default amongst negative-equity borrowers is driven by liquidity shocks or wealth maximization is an empirical question that is debated in the literature. After many years of widespread negative equity following the crisis, we saw that not all borrowers exercise the default option when it appears strictly in their economic interest to do so. Many borrowers continue to pay their mortgages even when their balances far exceed their home values. Foote, Gerardi, and Willen (2008) use data from Massachusetts to track the impact of a downturn in the early 1990s during which housing prices in Massachusetts fell roughly 20 percent from peak to trough. They find that just six percent of negative-equity borrowers went to foreclosure during that time, which, they argue, indicates that negative equity is often not a sufficient condition for default. They use this evidence to support the "double-trigger" theory of default – the idea that most defaults are driven by the confluence of negative equity and liquidity shocks.

However, researchers have found evidence that, in some cases, negative equity can be sufficient condition for default. Ghent and Kudlyak (2011) find that, all else equal, negative-equity borrowers in states where the lender may seek recourse for unpaid mortgage debts are somewhat less likely to default than borrowers in states that prohibits recourse, despite the fact that recourse is rarely actually pursued by lenders. Borrowers' sensitivity to the possible liabilities arising from mortgage default suggests that some borrowers do, in fact, strategically exercise the default option where it is available, and that default is not entirely driven by economic shocks. Bhutta et al. (2010) find

evidence of a negative equity threshold above which factors associated with liquidity shocks – unemployment and credit card delinquency rates, for example – lose importance in predicting default. Bajari et al. (2010) use a structural approach to separately estimate the influence of payment shock and negative equity on the default probabilities of subprime borrowers. They also find that negative equity is an important driver of default, along with economic shocks (either payment or income shocks) and credit constraints. Laufner (2013) finds that borrowers who extracted equity during the surge in home prices defaulted at much higher rates than borrowers who chose not to.

These empirical papers rely on variation in negative equity driven by the financing decisions of borrowers (timing of home purchase or equity extraction) and variation in local home prices, and use local economic trends, such as unemployment rates and credit card default rates, to identify probable changes in economic shocks. The acknowledged drawbacks to these methods when assessing the causal influence of negative equity, and in turn, how sensitive borrowers are to the pure financial features of their mortgage, are two-fold: first, that variation in negative equity driven by local price changes and both the timing and initial leverage of the mortgage is plausibly correlated with unobservable borrower characteristics that also predict default; and second: the fact that local economic changes are correlated with home price expectations. Default responses to changes in local unemployment rates may actually reflect strategic responses, as future prices look increasingly improbable. Economic shocks may appear to explain a larger share of defaults than is appropriate, given this interaction, and downwardly bias estimates of equity's contribution to default, perhaps particularly in lower LTV ranges, where near-term home-price growth will determine the difference between negative- and positive- equity.

Several researchers have evaluated the impact of payment reduction on mortgage default, using recent downward adjustments in ARM loans (Fuster and Willen, 2015)

and cite Tracy Wright 2012 and the large-scale refinancing program for Fannie Mae and Freddie Mac loans, HARP (McManus et al., 2015). These researchers have found that reducing payments reduces subsequent default rates substantially, even among performing borrowers and borrowers with a broad spectrum of equity positions.

Eberly and Krishnamurthy (2014) use a theoretical model to argue mortgage contracts with stabilizing features that reduce payments through rate reduction in widespread housing market downturn would be more efficient than principal forgiveness, in part because rate reductions increase the present value of remaining in the home by decreasing the present value of cash payments, while also improving liquidity. Likewise, Fuster and Willen (2015) argue that there is a mortgage payment for which, at almost every path of home price expectations, remaining in the home is optimal for a borrower in almost any degree of negative equity. As they note, this is the case because, in practice, lower payments – particularly those achieved through rate reduction, as in refinances or downward ARM rate resets – lower the present value of the payments borrowers owe on their mortgage.

The drivers of default are important for predicting the effectiveness of various modifications to stabilize those borrowers. The determinants of borrower default from a modification should depend largely on the reasons for the delinquency or distress that landed the borrower in a modification. By the same token, understanding what methods prevent default from mortgage modifications can teach us about the original default drivers. Purely strategic defaulters might be stabilized only by a large wealth transfer, such as principal forgiveness or generous rate reduction. Borrowers who would have continued to make payments absent an economic shock will be stabilized equivalently by any modification that results in the same final payment, regardless of the wealth transfer embodied in the modification. For the lender, the cost per dollar of payment reduction of these modification options varies widely. If borrowers are indifferent to the

structure of the modification, lenders may choose the option that presents the least cost for a given decrease in default probability. Likewise, the government – which subsidizes the HAMP program, and a vested interest in the financial performance of the GSEs – is interested in achieving the greatest default-reduction per dollar of subsidy.

Since the housing market downturn, several researchers have evaluated private-sector modification programs and their impact on borrower default. Haughwout et al. (2010) look at payment-reducing private-sector modifications that pre-date HAMP and find that payment reduction is an important determinant of default but that the borrower's equity position also plays a role. Das (2012) evaluates loan modifications in a theoretical framework, where borrowers are assumed to default or refinance for reasons strictly related to their observable mortgage features and potential income and home price volatility, and finds that principal reduction to be the most cost-effective means of loss-mitigation. Agarwal et al. (2011) find that payment reductions - particularly achieved through rate reduction - are critical to subsequent borrower reperformance; they estimate that a 1 percentage point decline in the borrower's mortgage rate is associated with a 4 percentage point decline in default probability following modification. Agarwal et al. (2012) look at the HAMP program specifically, using discontinuities in eligibility criteria to adjust for selection effects of the HAMP program. They look specifically at whether HAMP crowded out other modification programs, and find some evidence that it did. Schmeiser and Gross (2015) surveys the recent history of modifications on loans in private label securitizations, and finds that rate reduction and principal reduction are particularly effective at lower subsequent default. The acknowledged drawback to these studies is that the mechanism for determining the structure of the modification is unobservable to the researcher, and is plausibly correlated with subsequent default performance.

Using an empirical strategy similar to that used in this paper, Scharlemann and

Shore (2015) find evidence that principal forgiveness decreases subsequent default, holding payment reduction constant, but is expensive. This finding suggests that borrowers are responsive to the wealth implications of their mortgage modification. Principal forgiveness and rate reduction have similar impacts on the wealth transfer embodied in the mortgage modification, given that, for example, 10 percent in principal forgiveness is approximately equal to a 1 percentage-point rate reduction amortized over 10 years.

It should be noted that the population receiving HAMP modifications is unusual in many ways, and the results of this analysis may therefore be difficult to extrapolate to the general population of mortgage borrowers. Most notably, these borrowers are very delinquent on their mortgages. The program may also select for a population that has a different baseline default rate than the general delinquent population. The HAMP modification has proven difficult to obtain: borrowers must gather substantial paperwork and fastidiously document income. The sample of borrowers in the HAMP program may therefore be among the least sensitive to the composition of their mortgage modification. That said, despite these obstacles, the HAMP modification may be valuable for borrowers with low home attachment as well. It is free, aside from administrative burden, and a successful modification re-starts the foreclosure timeline, which may be valuable for borrowers because doing so extends the period during which the borrower may occupy the home rent-free, as they wait for foreclosure. We have little evidence either way on whether borrowers are broadly aware of and exploit these features of the program. On balance, it is difficult to know how the population of HAMP borrowers compares with similar borrowers who did not receive HAMP modifications.

1.2 The HAMP Modification

HAMP is a federal program that provides subsidies to servicers, borrowers, and investors for modifications of mortgages that are delinquent or in imminent default. Participating servicers are required to modify the terms of eligible mortgages that are held on portfolio or serviced on behalf of mortgage investors; participating servicers may not select which mortgages to modify or what type of modification to grant. Participants in the HAMP program service over 80 percent of outstanding first lien mortgages.

The HAMP program prescribes a series of specific steps to bring the borrower's first lien debt-to-income (DTI) ratio (including taxes and insurance) to no more than 31 percent of their monthly mortgage payments as a share of their pre-tax income. In the program I evaluate – the original HAMP modification – borrowers with an initial DTI below 31 percent are ineligible for the basic HAMP modification. This 31 percent DTI ratio will hereafter be referred to as the "DTI target".

The procedure for achieving the DTI target is as follows: first the interest rate on the mortgage is lowered until the payment target is met. If the borrower's DTI remains above the target DTI at a 2 percent interest rate, the servicer must extend the term of the mortgage until the payment target is met, or until the term reaches 480 months. If necessary, the servicer forbears principal until the payment target is met. The principal forbearance takes the form of a non-interest-bearing balloon, payable at maturity or upon prepayment of the mortgage. The impact of forbearance on the modification payment is equivalent to principal reduction, but unlike principal forgiveness, forbearance must be repaid.

While the term extension and the forbearance portion of the mortgage persist for the life of the mortgage, the interest rate does, in many cases, increase over time. If the borrower's modified mortgage rate is below the Freddie Mac Primary Mortgage Market

Survey (PMMS) rate at the time of the modification, the modification rate remains in place for five years. Beginning in the 5th year, the rate rises by one percentage point per year until the modification rate equals the PMMS rate that prevailed at the time of the modification. Borrowers with modified mortgage rates above the PMMS rate at the time of the modification do not face interest rate increases; their rate remains fixed for the duration of the modification.

The HAMP modification permanently changes the terms of the mortgage. However, before receiving a permanent change in terms, borrowers must complete a trial period, during which they are required to make their new, lower mortgage payments. The trial period is a minimum of 3 months for borrowers with non-GSE mortgages and 4 months for borrowers with GSE mortgages. Once the borrower has successfully completed the trial period, she is eligible for a permanent modification, at which point the investor, servicer, and borrower become eligible for government incentives. The HAMP program originally allowed servicers to initiate trial modifications based on borrowers' own estimates of their incomes. Many of these trial modifications initiated based on stated income took a very long time to convert into permanent modifications because servicers and borrowers struggled to assemble the required documentation for the modification. The trial periods during the earlier portion of the program tended to be far longer than the statutory minimum, and therefore these modifications have generally seasoned somewhat longer before becoming permanent.

The borrower loses good standing under HAMP when she becomes more than 90 days delinquent on her mortgage payment. Ninety-day delinquency is therefore the event observed in this dataset that best approximates default, and which I call "default" throughout. However, falling out the program – going 90 days delinquent – does not necessarily mean the borrower ultimately proceeds to foreclosure. In fact, the final disposition of the loan likely varies with observable features of the loan, such as the

borrower's loan-to-value ratio. Unfortunately, I cannot observe the ultimate outcome for borrowers who fall out of the HAMP program.

1.3 Variation in terms, variation in value

The wealth embodied in the mortgage modification depends on the change in present value of the cash flows associated with the terms of the mortgages before and after modification over the time-frame that is relevant to the borrower.

The cash flows for the modification reflect the initial modification terms, the borrower subsidy included in the HAMP modification (the minimum of \$1,000 or 50 percent of the payment reduction per year, accrued on a monthly basis), and, if applicable, annual interest-rate step-ups for modifications with below-market interest rates. The present value calculation for the cashflows associated with the modification at time t is:

The present value of the cashflow associated with the unmodified loan is:

$$PV_0 = C + \sum_{t=1}^{T-1} \frac{(B_{0,t})(r_{0,t}(1 + r_{0,t}^{n_{0,t}}))}{((1 + r_{0,t})^{n_{0,t}} - 1) * (1 + \delta)^t} + \frac{B_T}{(1 + \delta)^T} \quad (1.1)$$

The present value of the cashflow associated with the modified loan is:

$$PV_1 = \sum_{t=1}^{T-1} \frac{(B_{1,t} - g_t)[r_{1,t}(1 + r_{1,t}^{n_{1,t}})]}{((1 + r_{1,t})^{n_{1,t}} - 1) * (1 + \delta)^t} + \frac{F + B_T}{(1 + \delta)^T} \quad (1.2)$$

$B_{1,t}$ is equal to the modified mortgage balance less forbearance (the amortizing balance) at time t and $B_{0,t}$ is equal to the remaining unpaid balance at time t . $B_{j,t}$ evolves as:

$$B_{j,t+1} = B_{j,t} - (mtg(B_{j,t}, r_{j,t}, n_{j,t}) - r_{j,t} * B_{j,t}) \quad (1.3)$$

Where r_t is the monthly interest rate on the mortgage at time t , n_t is the remaining term, δ is the discount rate, T is the time horizon of the borrower, g_t is the government subsidy to the borrower (applied directly to the unpaid balance), F is the forbearance amount associated with the modification and C is the capitalized past-due amount that the borrower must repay in order to become current and resume their normal mortgage payments. The index j equal 0 to indicate the pre-modification mortgage and 1 to indicate the modified mortgage. To review, the interest rate on the modified loan is fixed for the first five years, and then – if the borrower’s initial modified rate is below the PMMS rate at the time of modification – the rate steps up 1 percentage point per year until the PMMS rate at modification is achieved. The government subsidy g_t is paid out only during the first 5 years of the modification ($t = 12, 24, 36, 48, 60$) and is equal to zero thereafter. The monthly payment for a fixed rate mortgage follows the standard formula:

$$\text{mtg}(B, r, t) = B * \frac{r * (1 + r)^t}{(1 + r)^t - 1} \quad (1.4)$$

The wealth transfer arising from the modification is the difference between these two values.

In Figure 1.1 I show the percentage change in the present value of the cash flows paid out by the borrower, assuming a 5 year horizon, a pre-modification remaining term of 25-years, and a payment reduction of 35 percent. The horizontal axis shows the borrower’s pre-modification mortgage rate. The discount rate is assumed to be 2 percent. Higher values indicate a greater value transfer to the borrower.

To the far left, the borrower’s original mortgage rate is low, and the borrower receives a rate reduction, term extension, and forbearance in order to achieve the 30 percent reduction in payment. There is a slight change in the slope of the relationship

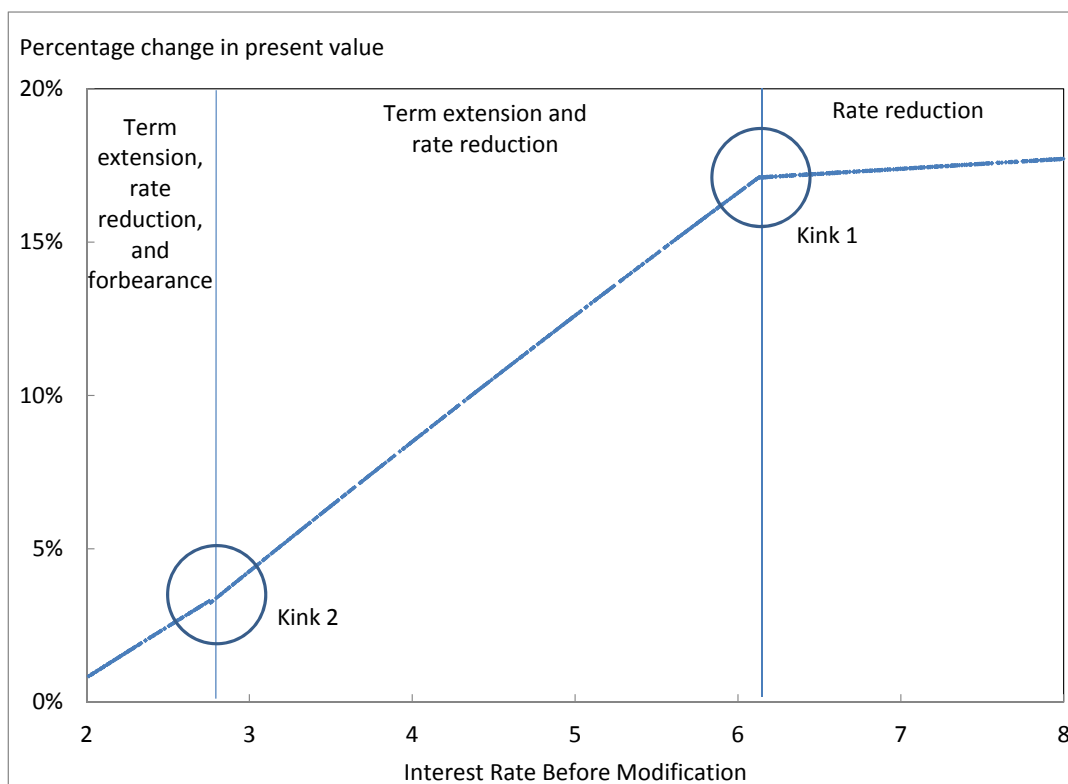


Figure 1.1: Percentage Change in Present Value of Mortgage Payments, by Pre-modification Mortgage Rate

between the percentage change in the present value of mortgage payments and the original mortgage rate, where forbearance becomes unnecessary; I call this "kink 2", as it is the second transition in the modification waterfall outlined in Section 1.2. Moving rightward along the horizontal axis, the original mortgage rate increases, and the percentage change in the present value of mortgage payments increases rapidly, as the mortgage is comprised increasingly of rate reduction, and the share comprised of term extension decreases. A sharp change in the slope of the relationship between the percentage change in the present value of mortgage payments and the original mortgage rate occurs again where the original mortgage rate is sufficiently high that term extension is not necessary to achieve the payment reduction. I call this transition "kink 1", because it is the first transition point in the mortgage waterfall.

Table 1.1: Modification Structure and Modification Value

	Pre-modification mortgage rate					
	2	3	4	5	6	7
Post-modification rate	2.0	2.0	2.0	2.0	2.0	2.7
Post-modification term	480	467	400	347	305	300
Forbearance (%UPB)	9.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Present value no modification (%UPB)	100%	104%	109%	113%	118%	123%
Present value modification (%UPB)	99%	100%	100%	100%	100%	103%
Percentage change in cash flows	0.8%	4.2%	8.1%	11.8%	15.3%	16.0%
Payment change from rate (%)	0.0%	10.6%	19.7%	27.5%	34.2%	35.0%
Payment change from term (%)	28.6%	24.4%	15.3%	7.5%	0.8%	0.0%
Payment change from forbearance (%)	6.4%	0.0%	0.0%	0.0%	0.0%	0.0%
Total payment change:	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%

Note: This exercise assumes a 5 year time horizon, a 2 percent discount rate, a 300-month remaining term before modification, and a 35 percent payment reduction.

Table 1.1 illustrates the modification structure for similar loans with different pre-modification mortgage rates, under the same assumptions as in Figure 1.1. The loan with the lowest original mortgage rate receives no rate reduction, and the entire modification is comprised of term extension and principal forbearance. The loan with the highest original mortgage rate is modified only using rate reduction. The value transferred to the borrower in the latter case is far greater.

In practice the measures used to capture the value of the modification are very rough. They do not account for the fact that the borrower may be able to refinance into a lower rate. They take a position on the relative value of deferred payments through the discount rate. A more complete model of the borrower's default problem would include other important inputs, such as the opportunity cost of capital invested in housing, home price expectations, and rental rates, such as in Campbell and Cocco (2015) and Hembre (2014).

None of these model enhancements would affect the location of the kinks, or the direction of the change in slope at the kinks, though different assumptions will affect both the level of the estimated wealth transfer and degree to which the slope changes at

each of the kinks.

1.4 Empirical Specification: Regression Kink Design

Each loan receives a payment reduction sufficient to bring their total front-end DTI ratio, including taxes and insurance, to 31%. To achieve the payment target, the borrower's monthly principal and interest payments are adjusted according to the series of steps described in Section 1.2. The borrower's rate reduction is the minimum required to achieve either the 2% rate target or the payment target. Likewise, conditional on requiring the full rate reduction, the term extension is the minimum necessary to reach either the payment target or 480 months. Two kinks are created: first, where the servicer transitions from using rate reduction to using term extension, and second, where the servicer transitions from using term extension to principal forbearance.

These kinks imply that, for the same percentage change in mortgage payment and the same remaining term at modification, borrowers with higher original mortgage rates receive modifications with greater rate reductions. Borrowers with lower original mortgage rates receive modifications with greater term extensions and principal forbearance. In other words, the relationship between pre-modification and post-modification mortgage rates changes discretely at the first kink, and the relationship between pre-modification rate and post-modification amortization term changes discretely at the second.

Table 1.1 shows the modification structure resulting from a 35% payment reduction on a series of fixed rate mortgages with 300-month amortization terms and different pre-modification interest rates. As we move from far left column of the table to the far right, the 35% payment reduction is increasingly achieved through rate reduction rather than term extension. The kink occurs at the pre-modification interest rate where, holding

constant the payment reduction, a marginal increase in the pre-modification mortgage rate eliminates the need for term extension (in other words, between a loan with a pre-modification mortgage rate of 6 percent and a loan with a pre-modification mortgage rate of 7 percent, in this example).

The inputs into the calculation of the loan's position relative to the two kinks are: the change in principal and interest payments (P&I) necessary to achieve the payment target, and, separately, the change in P&I associated with achieving each of the rate floor (2%) and the maximum term extension (480 months). Following Scharlemann and Shore (2015), suppose the change in principal and interest (P&I) required to reach the DTI target is:

$$\begin{aligned} \text{PMT}_{DTI} &\equiv \frac{\text{pre-modification P\&I}}{\text{target P\&I}} - 1 \\ \text{PMT}_{DTI} &\equiv \frac{\text{mtg}(B_0, r_0, t_0)}{0.31 * \text{income} - \text{fixed payments}} - 1 \end{aligned} \quad (1.5)$$

Note that PMT_{DTI} is greater than zero, and increasing in the payment reduction. The change in payment implied by the 2% rate floor is:

$$\text{PMT}_{\text{ratefloor}} \equiv \frac{\text{mtg}(B_0, r_0, t_0)}{\text{mtg}(B_0, 0.02, t_0)} - 1 \quad (1.6)$$

From these equations we see that, all else equal, there exists an r_0^{k1} such that PMT_{DTI} equals $\text{PMT}_{\text{ratefloor}}$. This r_0^{k1} defines the kink point. Where $r_0 > r_0^{k1}$, the borrower's payment reduction is comprised entirely of rate reduction. Where $r_0 < r_0^{k1}$, the borrower's payment reduction includes term extension.

I define the payment reduction arising from rate reduction as:

$$\text{PMT}_R \equiv \min(\text{PMT}_{\text{ratefloor}}, \text{PMT}_{\text{DTI}}) \quad (1.7)$$

The change in payment implied by the 480-month limit on the amortization term is:

$$\text{PMT}_{\text{termlimit}} \equiv \frac{\text{mtg}(\text{B}_0, r_0, t_0)}{\text{mtg}(\text{B}_0, 0.02, 480)} - 1 \quad (1.8)$$

For sufficiently large PMT_{DTI} there exists an r_0^{k2} , such that PMT_{DTI} equals $\text{PMT}_{\text{termlimit}}$. The value of r_0^{k2} defines the second kink point. Where $r_0 \leq r_0^{k2}$, the borrower's payment reduction is comprised entirely of rate reduction and term extension. Where $r_0 > r_0^{k2}$, the borrower's payment reduction includes principal forbearance.

The formulas identifying the location of the kink rely on servicers following the standard waterfall formula. I assess the accuracy of this assumption by regressing the true values of the payment change arising from rate reduction and term extension, separately, on my estimates of these values. I predict the true modification structure with very high accuracy: the R^2 on each of these regressions is over 0.99.

I take the natural log of the variables defined in equations 1.5, 1.7, and 1.8 and estimate the default probability around each kink in separate equations, using only the subset of loans relevant for the kink point in question. The equation estimating default using the subsample of loans relevant for the first kink (loans with rate reduction and loans with both rate reduction and term extension but no forbearance) is shown in equation 1.10.

$$\begin{aligned}
\Pr(\text{Default}_{i,t}) = f(\alpha &+ \beta_R \ln(1 + \text{PMT}_{R,i}) \\
&+ \beta_{\text{DTI}} \ln(1 + \text{PMT}_{\text{DTI},i}) + \beta_{\text{ratefloor}} \ln(1 + \text{PMT}_{\text{ratefloor},i}) \\
&+ \beta_t * (t_{0,i}) + \beta_r(r_{0,i}) \\
&+ \beta_X X_{i,t} + \epsilon_{i,t})
\end{aligned} \tag{1.9}$$

The coefficient on the second term, β_R approximates the effect of a given percentage change in payment arising from rate reduction, all else equal, on the log-odds of default. The other terms control for the loan's distance from the kink. These terms are time-invariant.

The vector X represents an additional set of controls. These include dummies for the month of modification and the duration of the modification in all specifications. Together these two sets of covariates control for the calendar month as well. Also included in some specifications are nonparametric controls for the payment change (in 2 log-point intervals), pre-modification mortgage rate (rounded to the nearest percentage point), and term (in 6-month intervals); delinquency at modification; borrower credit score at modification; origination year of the original mortgage; estimates of the modification- and no-modification present value of cashflows for the investor using the HAMP NPV model; delinquency at the time of modification; the borrower's LTV ratio; and quadratic terms for each of the covariates. Errors are clustered by MSA.

My null hypothesis is that β_R is equal to 0. This result is consistent with the borrower being insensitive to the composition of the payment reduction. A negative, statistically significant coefficient would suggest that default is decreasing in the payment change arising from rate reduction. A positive, statistically significant coefficient would be inexplicable within my theoretical framework.

Similarly, the equation estimating default using the subsample of loans relevant for the second kink (loans with rate reduction and term extension, loans with forbearance, but not loans with only rate reduction) is shown in equation 1.11.

$$\begin{aligned}
 \Pr(\text{Default}_{i,t}) = f(\alpha &+ \beta_T \ln(1 + \text{PMT}_{T,i}) \\
 &+ \beta_{DTI} \ln(1 + \text{PMT}_{DTI,i}) + \beta_{\text{termlimit}} \ln(1 + \text{PMT}_{\text{termlimit},i}) \\
 &+ \beta_t * (t_{0,i}) + \beta_r(r_{0,i}) \\
 &+ \beta_X X_{i,t} + \varepsilon_{i,t})
 \end{aligned} \tag{1.10}$$

The coefficient on the second term, β_T approximates the effect of a given percentage change in payment arising from term extension, all else equal, on the log-odds of default. The other terms control for the loan's distance from the kink.

My null hypothesis is that β_T is equal to 0. A positive, statistically significant coefficient would suggest that default is increasing in the payment change arising from term extension, relative to forbearance, and is consistent with borrowers responding to a slight change in the wealth transfer associated with their mortgage. A negative, statistically significant coefficient would be inexplicable within my theoretical framework.

1.5 Validity of RKD

Card et al. (2012) present two main identifying assumptions under which the RKD method can recover the effect of treatment on the treated. First, the probability density must be continuously differentiable in the assignment variable (in this case, mortgage composition). This is to ensure that subjects cannot or do not manipulate the intensive or extensive margins of the treatment (i.e., whether they are treated, and if

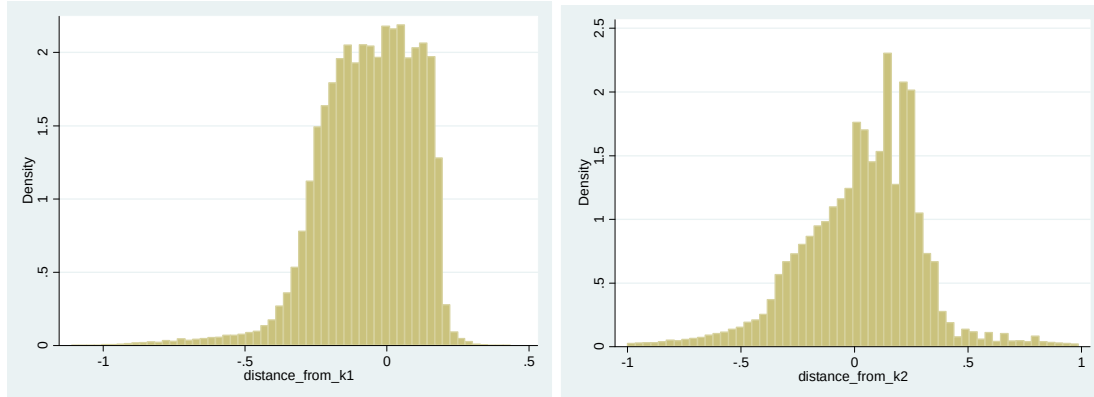


Figure 1.2: Distribution of Borrowers Relative to the Two Kinks

so, by how much). Second, attributes of the subjects must be continuously differentiable at the kink point – subjects on either side of the kink must not be substantially or discontinuously different from one another.

Applied to this paper’s problem, the first assumption implies that borrowers and servicers cannot manipulate their mortgage terms or income in order to affect their position relative to the kinks. Because the mortgage modification structure is determined based on the borrower’s contractual mortgage terms and a payment reduction documented using tax records and recent pay stubs, it seems unlikely that borrowers would exercise much control over the structure of their modification. Figure 2.9, which shows histograms of borrowers’ positions relative to each kink, reveals no evidence of bunching.

Since RKD is typically a low-power methodology (Card et al., 2012), researchers may need to include observations far from the policy kink in order to precisely estimate a treatment effect. As Ganong and Jager (2014) and others have noted, this can be problematic. As loans farther from the kink are included in the estimation sample, a nonlinear relationship between the variables that determine treatment (i.e., distance from the kink) and the outcome variable may be captured in the coefficient representing the slope change of the outcome variable. This is particular true if, as in most RKD exercises, a

single covariate determines the policy treatment, and all observations a given distance from the kink share a single value for that covariate. Researchers typically use a variety of parametric approaches to minimize this problem, including introducing quadratic and cubic transformations of the control variable and interactions with other covariates. Scharlemann and Shore (2015) demonstrate that a two-dimensional kink, where a combination of two control variables determine the treatment, allows researchers to control nonparametrically for the variables determining the treatment, thereby minimizing the probability that the RK coefficient is biased. The RKD strategy in this paper is similar to that in Scharlemann and Shore (2015), in that the location of a specific borrower relative to the kink is determined in several dimensions: pre-modification interest rate, pre-modification mortgage term, and the percentage reduction in monthly principal and interest payments necessary to achieve the 31 percent DTI target. The multidimensional nature of the kink allows me to control nonparametrically for the inputs that determine the modification structure, thereby minimizing the potential misattribution of structural relationships in the data to policy treatments.

1.6 Data Description and Summary Statistics

The primary source of data is the publicly available dataset derived from the system of record for the Home Affordable Modification Program. These data include geographic information, property value, the household's monthly income, and basic information about the terms of the mortgage, both before and after the modification. Detailed data on applicants rejected from the HAMP program are not available. Information on borrowers who fail trial modifications tends to be less reliable than information on borrowers who receive permanent modifications; in particular, one cannot clearly distinguish defaults from other reasons for fall-out, including ineligibility. I therefore

exclude trial modifications from my sample. Because the quality and coverage of the variables in the administrative dataset varies, my analysis relies primarily on the fields within the HAMP data that are well-audited: fields related to the eligibility of the borrower, fields reliably maintained in servicer databases (such as borrower address), and fields that directly determine incentive payments.

My sample includes only fixed rate mortgages backed by Fannie Mae and Freddie Mac. I have limited my sample to GSE loans because the public HAMP data do not allow the researcher to distinguish loans held on portfolio, which must follow the modification formula exactly, from loans held in private label securitizations, which often have investor restrictions that override HAMP rules.

Focusing on GSE loans also requires limiting my sample to loans that were not in-the-money to refinance within the observation period. GSE borrowers with high rates on their HAMP modification were often in the money to refinance during the observation period, and many did. Because these borrowers had the option to refinance, they defaulted for fundamentally different reasons than did borrowers without that option. The borrowers with high post-modification interest rates are universally far from the policy kinks I evaluate, so eliminating them does not bias the estimate of the policy change arising from the kink.

The outcome variable of interest is default, measured as 90-day delinquency. Following 90-day delinquency, borrowers are disqualified from the HAMP program, and subsidy payments to all parties cease. Loans that have been disqualified from the program are not monitored, so I cannot determine the final disposition of these loans. This definition of default is the same as in Scharlemann and Shore (2015) and Bhutta et al. (2010), among others. I do not focus on prepayment in this exercise, because prepayment rates among borrowers with post-modification mortgage rates that place them near the policy kink are exceedingly low. I do not have sufficient power to identify

any change arising from the policy kink.

Borrowers are granted HAMP modifications based on the outcome of a model that compares the expected cashflows to the investor with and without the modification. The model's main engine is a default model, which incorporates the degree of delinquency at modification, the borrower's credit score, the payment reduction arising from the modification, and the borrower's LTV. The model also incorporates information that varies by geography, such as REO timelines and foreclosure costs and home price projections. I pull inputs and outputs from the NPV model from a separate file made available by the MHA program.

Information about second liens is not captured at all. Measures for combined loan-to-value ratio are therefore unavailable. The paucity of combined loan information is a near-universal problem facing researchers using loan-level, servicer-provided data, because the servicer does not have direct access to accurate information about subordinate liens attached to a specific property unless that lien happens to be held by the servicer of the first lien. However, unlike other datasets used for this type of analysis, where updated LTVs are estimated using local price indexes, the property value is updated for HAMP evaluation using an Automated Valuation Model (AVM) where possible, and an appraisal or broker price opinion when a high-quality AVM is not available. While any non-sale estimate is imperfect, the home value information in HAMP will generally be more accurate than adjustments using broader geographic price indexes. The omission of second-lien information is not a source of bias for the main variables of interest. The structure of the modification is uncorrelated with total indebtedness, except to the extent that total indebtedness is correlated with the payment reduction, which is controlled for separately.

I use a 10 percent sample of loan-months that enrolled in the HAMP program during the first 4 years. I include all loan-months with defaults, and adjusting their

Table 1.2: Summary Statistics: Loans Included in Kink 1 Regressions

	N	Mean	Median	St. Dev	Min	Max
Pre-modification DTI (%)	144,725	44.8	44.2	5.8	31.0	100.2
Post-modification DTI (%)	144,725	31.0	31.0	0.4	16.1	32.0
Pre-modification principal & interest	144,725	1,357.4	1,263.2	588.8	135.8	5,289.7
Post-modification principal & interest	144,725	847.4	783.9	387.3	63.1	3,356.4
Pre-modification interest rate	144,725	6.4	6.4	0.7	2.3	12.4
Post-modification rate	144,725	2.3	2.0	0.5	2.0	3.5
Pre-modification remaining term	144,725	305	318	46	120	360
Post-modification remaining term	144,725	349	336	64	108	480
Principal forbearance	144,725	0.0	0.0	0.0	0.0	0.0
Payment change from interest (%)	144,725	36.5	37.3	6.1	2.6	63.0
Payment change from rate (%)	144,725	18.2	15.9	8.1	7.8	63.1
Payment change from forbearance (%)	144,725	0.0	0.0	0.0	0.0	0.0
Total payment change (%)	144,725	54.8	53.9	4.6	25.5	77.9
Credit score	130,130	605	590	92	250	900
Loan to value ratio	144,723	297.0	109.0	312	0.1	77,106

relative weight accordingly in the weighted regressions that are used throughout this project. The first sample includes 144,725 unique loans and 634,420 loan-months. The second sample includes 150,729 unique loans and 678,833 loan-months. The first cohort of loans received permanent modifications in September 2009; I follow the performance of this cohort of loans for 64 months. The last cohort of loans received modifications in September 2013; I follow the performance of this cohort of loans for 16 months.

Table 1.2 and Table 1.3 show summary statistics for loans in the samples used to estimate the effect of rate reduction relative to term extension and term extension relative to forbearance, respectively. The first sample includes loans with rate reduction or rate reduction and term extension; loans with forbearance are excluded. The second sample includes loans with term extension or term extension and forbearance; loans that require only rate reduction are excluded. The loans in the sample used to evaluate the two kinks are very similar, with the notable difference that the payment reduction

Table 1.3: Summary Statistics: Loans Included in Kink 2 Regressions

	N	Mean	Median	St. Dev	Min	Max
Pre-modification DTI (%)	150,729	52.8	50.5	11.0	31.1	392.8
Post-modification DTI (%)	150,729	31.0	31.0	0.6	13.7	32.0
Pre-modification principal & interest	150,729	1,405.8	1,313.0	601.4	111.9	5,531.2
Post-modification principal & interest	150,729	700.6	644.9	337.5	1.4	3,356.4
Pre-modification interest rate	150,729	6.4	6.4	0.7	2.3	12.4
Post-modification rate	150,729	2.0	2.0	0.0	2.0	2.0
Pre-modification remaining term	150,729	307	318	46	120	360
Post-modification remaining term	150,729	414	438	75	108	480
Principal forbearance	150,729	19155	0	37165	0	495500
Payment change from interest (%)	150,729	36.8	37.5	6.1	2.6	62.8
Payment change from rate (%)	150,729	17.9	15.7	8.0	7.2	63.1
Payment change from forbearance (%)	150,729	3.7	0.0	6.5	0.0	50.3
Total payment change (%)	150,729	58.3	56.1	7.4	25.5	99.9
Credit score	135,837	604	591	90	250	900
Loan to value ratio	150,727	292.3	115.5	301	0.4	77,106

required to achieve the DTI target in the second sample is larger.

Figure 1.3 shows monthly enrollment into the HAMP program by GSE loans. Figure 1.4 shows average monthly default hazards in different cohorts (left panel) and as modifications season (right panel).

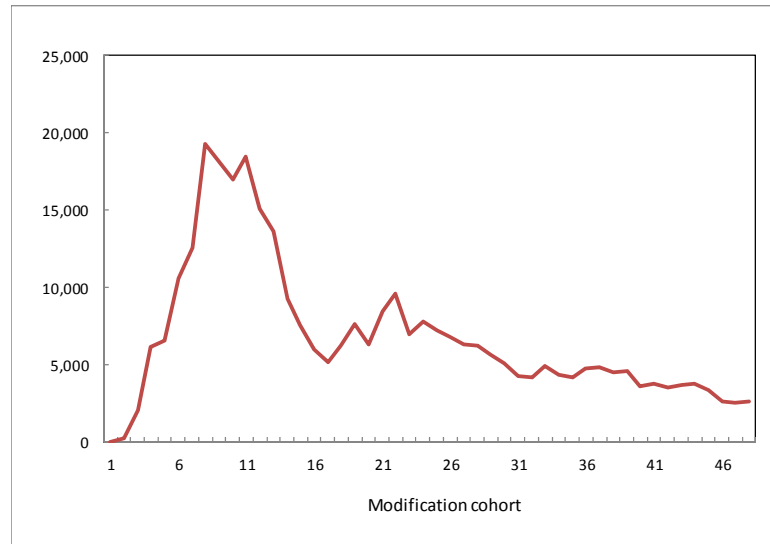


Figure 1.3: Monthly Enrollment of Fannie Mae and Freddie Mac Loans in HAMP

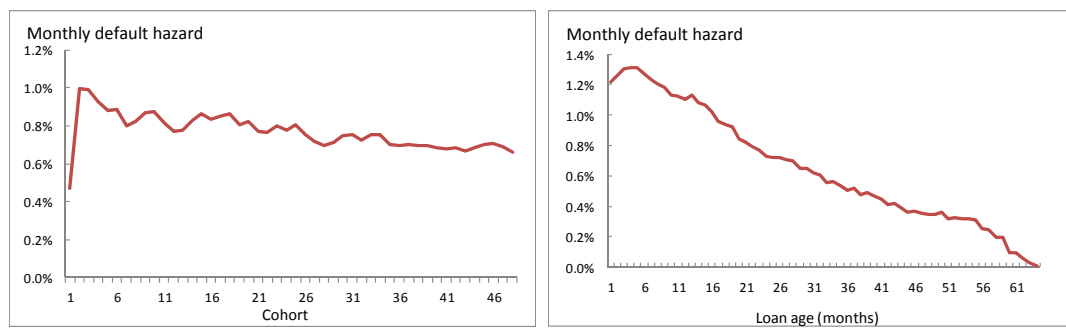


Figure 1.4: Monthly Default Hazard by Cohort and Loan Age

1.7 Results

Table 1.4 shows the results of the baseline regression, shown in Equations 1.10 and 1.11. The coefficient on the variable of interest for kink one, which estimates the effect of increasing rate reduction relative to term extension, varies from -0.67 to -1.33, and is statistically significant in all specifications. The coefficient on the variable of interest for kink two, which estimates the effect of increasing term extension relative to principal forbearance, varies from -0.47 to 0.37, and is statistically significant in three of the four specifications. The instability of this coefficient suggests that while the large volume of data enables precise estimation in some cases, the relationship between the policy treatment and the outcome variable is not robust.

Moving from the left to the right in Table 1.4, the specifications include additional parametric and nonparametric covariates designed to control for potential non-linear relationships between the variables that determine the policy treatment and the outcome variable, default.

Table 2.7 focuses on the areas immediately surrounding the kinks, using the specification in column 3 of Table 1.4 (though all of the specifications in Table 1.4 yield similar results). As the sample includes loans in an increasingly narrow area around the kink, the coefficient on $\ln(1 + \text{PMT}_R)$ remains stable and statistically significant. Where the distance from the kink falls below 15 log-points, the coefficient loses power. The coefficient on $\ln(1 + \text{PMT}_T)$ is unstable and is not statistically differentiable from zero once loans farther than 40 log-points from the kink are excluded. From this, I infer that no statistically detectable change in borrower default occurs at the transition point between term extension and principal forbearance, and I cannot reject my null hypothesis that the borrower is indifferent between these two forms of payment reduction.

Figure 2.3 illustrates the change in the outcome variable around the first kink. The red squares are the coefficient on 5 log-point bins of $\ln(1 + \text{PMT}_R) - \ln(1 + \text{PMT}_{DTI})$ (distance from the first kink), from the following regression:

$$\begin{aligned} \text{Pr}(\text{Default}_{i,t}) = f(\alpha &+ \sum_k \mathbb{1}_k \text{distance from kink bin} * \beta_k \\ &+ \beta_{DTI} \ln(1 + \text{PMT}_{DTI,i}) \\ &+ \beta_t * t_{0,i} + \epsilon_{i,t}) \end{aligned} \quad (1.11)$$

Equation 2.3 reformulates Equation 1.10 so that the pre-modification interest rate varies. Because payment change and pre-modification term are held constant, variation in the original mortgage rate determines the treatment entirely. Loans with negative values for $\ln(1 + \text{PMT}_R) - \ln(1 + \text{PMT}_{DTI})$ are in the region of the modification waterfall where the payment reduction required to reach the DTI target exceeds the payment reduction implied by the rate reduction. These borrowers require term extension. Increasing the borrower's pre-modification mortgage rate (moving right on the horizontal

axis in 2.3 increases the payment reduction arising from rate reduction ($\ln(1 + \text{PMT}_R$. Loans with positive values for $\ln(1 + \text{PMT}_R) - \ln(1 + \text{PMT}_{DTI})$ are in the region of the modification waterfall where the payment reduction implied by the rate floor exceeds the payment reduction required to reach the DTI target. These borrowers have not received a rate reduction to 2 percent, and increasing their pre-modification mortgage rate increases their post-modification mortgage rate.

The black lines show the coefficients from a specification similar to Equation 1.11 that replaces the 5-point dummies with the linear term $\ln(1 + \text{PMT}_R) - \ln(1 + \text{PMT}_{DTI})$ and an interaction with with an indicator variable that equals one if the distance from the kink is positive. The grey line helps to illustrate the change in slope at the kink. I have elongated the chart to better illustrate the slope-change at the kink, and I have added error bars to represent the 95 percent confidence interval on each of the points (relative to the omitted category, at the kink).

Table 1.4: Monthly Hazard: Impact of Modification Terms on Program Exit

	Dependent: Monthly Default Hazard			
	(1)	(2)	(3)	(4)
First kink: rate reduction vs term extension				
$\ln(1+\text{PMT}_R)$	-1.332*** (0.122)	-0.964*** (0.146)	-0.971*** (0.155)	-0.675*** (0.162)
Frequency-weighted N	5,877,266	5,877,266	5,876,924	5,273,446
Number of loan-months	632,255	632,255	632,255	567,382
Number of unique loans	144,711	144,711	144,711	130,113
pseudo R^2	0.0239	0.0241	0.0259	0.0424
Second kink: term extension vs forbearance				
$\ln(1+\text{PMT}_T)$	-0.474*** (0.069)	-0.053 (0.078)	0.478*** (0.141)	0.375** (0.149)
N	6,404,073	6,404,073	6,396,808	5,753,408
Number of loan-months	676,464	676,464	676,464	607,838
Number of unique loans	150,726	150,726	150,726	135,722
pseudo R^2	0.0208	0.0205	0.0231	0.0404
Controls				
Loan cohort and modification dummies	x	x	x	x
$\ln(1+\text{PMT}_{DTI})$	x	x	x	x
$\ln(1+\text{PMT}_{\text{ratefloor}})$ (kink 1)	x	x	x	x
$\ln(1+\text{PMT}_{\text{termlimit}})$ (Kink 2)				
pre-modification mortgage rate	x	x	x	x
pre-modification mortgage term	x	x	x	x
Quadratic in payment change, pre-mod mortgage rate, pre-mod mortgage term	0	x	0	0
2 log-point bins of $\ln(1+\text{PMT}_{DTI})$	0	0	x	x
1 ppt bins of pre-modification mortgage rate	0	0	x	x
6-month bins of pre-modification mortgage term	0	0	x	x
Other controls	0	0	0	x

Note: "Other controls" include FICO, NPV test results with and without modification, $\ln(\text{income})$, $\ln(\text{upb})$, $\ln(\text{tv})$, and delinquency at modification.

Table 1.5: Monthly Hazard: Regression Kink Design

	Dependent: Monthly Default Hazard						
	d <0.4	d <0.35	d <0.30	d <0.25	d <0.2	d <0.15	d <0.1
First kink: rate reduction vs term extension							
	$d = \ln(1+\text{PMT}_{\text{ratefloor}}) - \ln(1+\text{PMT}_{\text{on}})$						
$\ln(1+\text{PMT}_R)$	-1.036*** (0.155)	-0.905*** (0.165)	-0.849*** (0.170)	-0.697*** (0.178)	-0.692*** (0.193)	-0.459** (0.222)	-0.480 (0.309)
Frequency-weighted N	5,876,924	5,692,896	5,609,347	5,446,893	5,111,343	4,592,410	3,595,680
Number of loan-months	612,954	604,159	587,037	551,628	496,330	388,341	261,767
Number of unique loans	140,336	138,215	134,113	125,988	113,359	88,669	59,487
pseudo R^2	0.0258	0.0255	0.0255	0.0254	0.0253	0.0245	0.0238
Second kink: term extension vs forbearance							
	$d = \ln(1+\text{PMT}_{\text{terminit}}) - \ln(1+\text{PMT}_{\text{on}})$						
$\ln(1+\text{PMT}_T)$	0.489*** (0.139)	-0.128 (0.185)	-0.160 (0.200)	-0.140 (0.221)	-0.247 (0.260)	-0.406 (0.316)	-0.728 (0.446)
Frequency-weighted N	6,396,808	5,698,644	5,472,450	5,067,865	4,327,392	3,626,011	2,654,105
Number of loan-months	602,484	578,637	535,915	457,383	383,149	280,139	197,049
Number of unique loans	134,981	129,401	119,381	101,518	84,971	61,975	43,400
pseudo R^2	0.0230	0.0228	0.0228	0.0230	0.0228	0.0219	0.0212
Controls							
Loan cohort and modification dummies	x	x	x	x	x	x	x
$\ln(1+\text{PMT}_{\text{on}})$	x	x	x	x	x	x	x
$\ln(1+\text{PMT}_{\text{ratefloor}})$ (kink 1)	x	x	x	x	x	x	x
$\ln(1+\text{PMT}_{\text{terminit}})$ (Kink 2)	x	x	x	x	x	x	x
pre-modification mortgage rate	x	x	x	x	x	x	x
pre-modification mortgage term	x	x	x	x	x	x	x
Quadratic in payment change, pre-mod mortgage rate, pre-mod mortgage term	0	0	0	0	0	0	0
2 log-point bins of $\ln(1+\text{PMT_DTI})$	x	x	x	x	x	x	x
1 ppt bins of pre-modification mortgage rate	x	x	x	x	x	x	x
6-month bins of pre-modification mortgage term	x	x	x	x	x	x	x
Other controls	0	0	0	0	0	0	0

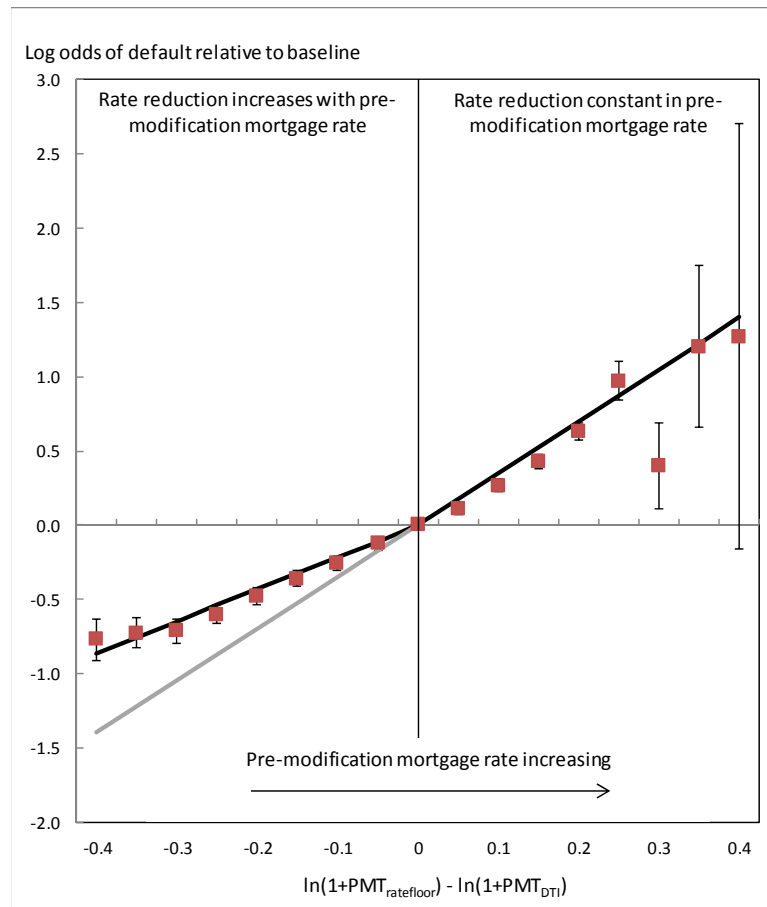


Figure 1.5: Monthly Hazard: Impact of Modification Terms on Program Exit

Table 2.9 estimates column 4 of Table 1.4 in subsamples, including high- and low-LTV loans, high- and low-pre-modification DTI borrowers, and loans that have seasoned for fewer than 24 months in the program versus loans that have seasoned for more than 24 months. I do not find meaningful variation in the impact of rate reduction on default in these subsamples.

Table 1.6: Monthly Hazard: Heterogeneity

	Dependent: Monthly Default Hazard						
	Full sample	LTV>140%	LTV<140%	TDI > 45%	TDI<45%	Mod age > 2 years	Mod age < 2 years
First kink: rate reduction vs term extension							
$\ln(1+\text{PMT}_R)$	-0.675*** (0.162)	-0.696** (0.340)	-0.612*** (0.186)	-0.981* (0.523)	-0.743*** (0.225)	-0.758** (0.309)	-0.667*** (0.190)
N	5,273,446	1,238,043	4,022,670	2,345,003	2,922,704	2,467,015	2,786,999
Number of loan-months	567,382	134,121	431,949	248,120	318,662	261,007	304,421
Number of unique loans	130,113	31,671	98,439	53,759	76,344	88,355	122,992
pseudo R ²	0.0424	0.0468	0.0415	0.0384	0.0411	0.0339	0.0322
Controls							
Loan cohort and modification dummies	x	x	x	x	x	x	x
$\ln(1+\text{PMT}_{DTI})$	x	x	x	x	x	x	x
$\ln(1+\text{PMT}_{\text{ratefloor}})$ (kink 1)	x	x	x	x	x	x	x
$\ln(1+\text{PMT}_{\text{termlimit}})$ (Kink 2)	x	x	x	x	x	x	x
pre-modification mortgage rate	x	x	x	x	x	x	x
pre-modification mortgage term	x	x	x	x	x	x	x
Quadratic in payment change, pre-mod mortgage rate, pre-mod mortgage term	0	0	0	0	0	0	0
2 log-point bins of $\ln(1+\text{PMT}_{DTI})$	x	x	x	x	x	x	x
1 ppt bins of pre-modification mortgage rate	x	x	x	x	x	x	x
6-month bins of pre-modification mortgage rate	x	x	x	x	x	x	x
Other controls	x	x	x	x	x	x	x

1.8 Conclusion

In the years since the financial crisis, policymakers and academics have had a spirited debate about the most efficient approach to mitigating the economic effects of widespread negative equity and the consequent high default rates. Some academics have argued that principal forgiveness is most effective because it resolves the a major driver of default, namely negative equity. Others have argued that negative equity is rarely the proximate cause of default, and improving liquidity among borrowers who experience economic shocks is of primary importance . Still others have argued for policies that effectively combine the two approaches: payment reductions that improve the wealth positions of borrowers.

This paper is the first to offer direct empirical evidence that borrowers are sensitive to the wealth component of payment-reducing modifications. I find strong evidence

that rate-reducing modifications are more effective at preventing subsequent default than modifications that do not affect the borrower's wealth. In fact, if the results of my analysis extend to performing borrowers, they suggest that nearly half of the improvement in performance seen in refinances and ARM resets can be attributed to the wealth transfer associated with the rate reduction.

The magnitude of the effect I find associated with rate reduction relative to term extension is similar to the effect Scharlemann and Shore (2015) find in comparing principal forgiveness to rate reduction. This makes sense. Over a plausible time horizon, rate reduction is more valuable relative to term extension than is principal forgiveness relative to rate reduction. Figure 1.6 shows the amortization rates of three different loans that start with a 6 percent mortgage rate and 300 month loan term. A 10% payment reduction is achieved through either reducing principal, reducing the mortgage rate, or extending the amortization term. Importantly, the present value of the cash flows from the current month to any future month are the same, regardless the mortgage structure. The difference in the value transferred to the borrower through these different modification structures is simply the difference between the amounts they have to pay back in each of these scenarios if they terminate the loan at time t . The vertical line shows the point where the difference between the value of the principal forgiveness and rate-reducing modification is equal to the difference between the rate-reducing and term extension modifications. This break-even point happens at 70 months, in this case. As the time horizon of the borrower extends, the difference between rate reduction and term extension grows, and the difference between principal forgiveness and rate reduction shrinks.

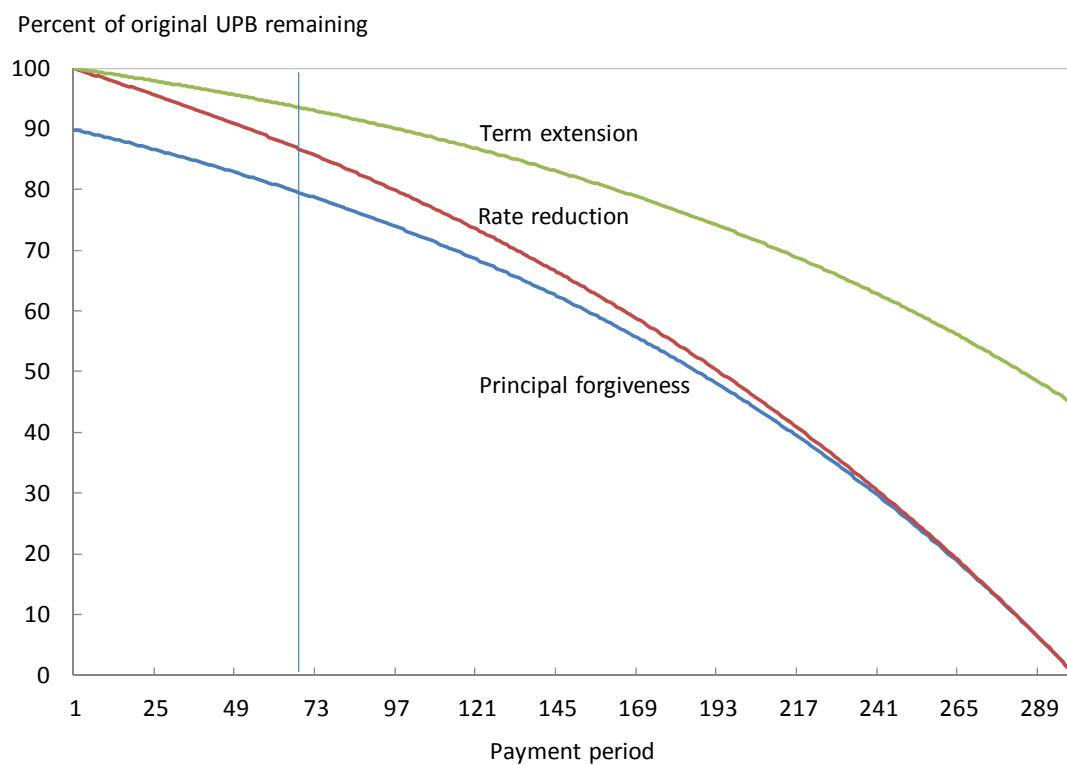


Figure 1.6: Amortization Rate of Mortgages with Same Payment and Different Terms

Without a clear estimate of the cost of the rate-reducing modification to the government, which will be included in future analysis, the policy implications of my findings are unclear. However, this analysis is a step toward evaluating the costs and benefits of proposed policies to address widespread negative equity and mortgage default.

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Chapter 2

The Effect of Negative Equity on Mortgage Default: Evidence From HAMP's Principal Reduction Alternative

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Abstract

The Home Affordable Modification Program's Principal Reduction Alternative (HAMP PRA) is a government-sponsored program to reduce the principal balances and monthly mortgage payments of borrowers with negative equity who are in danger of default. We use administrative data to examine the impact of principal forgiveness – a

permanent mortgage balance reduction – on borrowers’ subsequent mortgage default. The program’s rules imply a kink in the relationship between principal forgiveness and a borrower’s initial equity level *ceteris paribus*. Our identification strategy exploits the quasi-experimental variation in principal forgiveness generated by this kink using a regression kink design (RKD), which compares the relationship between initial equity and default on either side of the kink. The quarterly hazard – the proportion of loans that become more than 90 days delinquent and consequently exit the program – in our sample is 3.1%; we estimate that it would have been 3.8% absent principal forgiveness, which averaged 28% of the initial mortgage balance.

2.1 Introduction

The Home Affordable Modification Program’s (HAMP’s) Principal Reduction Alternative (PRA) subsidizes mortgage investors and servicers to provide payment reduction and principal forgiveness to borrowers whose mortgages have negative equity — mortgage balances in excess of their home value — and who are in danger of default. Payment reduction reduces the debt-to-income (DTI) ratio of the mortgage, making it more affordable; principal forgiveness reduces the loan-to-value (LTV) ratio of the mortgage, reducing negative equity. We use administrative data on HAMP PRA to estimate the causal impact of principal forgiveness on subsequent mortgage default.

This paper assesses principal forgiveness as a loss mitigation strategy for delinquent mortgages during the financial crisis. As such, it informs the design of mortgage modifications going forward. Eberly and Krishnamurthy (2014) have developed a theory of optimal modification design suggesting that payment reduction is likely to be a more powerful intervention in mortgage modifications than principal forgiveness. Clean evidence on the causal effects of principal forgiveness has been limited to date. Such

evidence would be relevant in policy debates such as proposals to include government sponsored enterprise (GSE, Fannie Mae and Freddie Mac) loans in HAMP PRA (Demarco, 2012).

Since principal forgiveness improves borrowers' home equity in a way that mimics home price appreciation, it also provides a channel for understanding the contribution of home price declines to the soaring mortgage default rates during the financial crisis. From the 4th quarter of 2006 through the first quarter of 2009, falling home prices reduced U.S. home equity by nearly \$5 trillion. By the fourth quarter of 2010, an estimated 12 million homes (25.4% of mortgages) had negative equity or were 'underwater' (CoreLogic, 2014), with mortgage balances exceeding the homes' values.¹ The share of active mortgages that were more than 90 days delinquent or in foreclosure shot from 2.2 percent in the fourth quarter of 2006 to a peak of 9.7 percent in the first quarter of 2010. (Mortgage Bankers Association, 2013) Because home price declines coincided with deterioration in the labor market, these two effects are difficult to disentangle using macroeconomic evidence alone.

To identify the causal effect of principal forgiveness on mortgage default, we exploit several kinks – discontinuities in the first derivative – in the function that determines the amount of principal forgiveness in HAMP PRA as a function of the borrower's initial equity level, *ceteris paribus*. These kinks allow the impact of principal forgiveness to be identified by exploiting the quasi-experimental variation in principal forgiveness from a regression kink design (RKD) (Florens et al., 2009; Card et al., 2012).

The primary kink arises because the amount of principal forgiveness is the minimum needed to reach an affordability target (post-modification DTI = 31%) and an

¹Researchers have raised concerns that negative equity may be associated with reduced mobility (Ferreira et al., 2010, 2013) (though this result has been contested in Schulhofer-Wohl (2012) and Demyanyk et al. (2013)), an inability to refinance mortgages into the recent low interest rate environment (Keys et al., 2014; Amromin and Kearns, 2014), and reduced consumption (Mian and Sufi, 2011; Dynan, 2012).

equity target (post-modification LTV, is constrained to be $\geq 115\%$ or $\geq 100\%$).² For any pre- modification DTI, there is a pre- modification LTV value such that the principal forgiveness implied by the DTI target and the LTV target are the same; this point is the “kink”. At pre- modification LTVs below the kink the LTV constraint binds, and principal forgiveness is increasing in pre- modification LTV.³ However, for pre- modification LTVs above this kink the LTV constraint does not bind, and principal forgiveness is unaffected by pre- modification LTV. We estimate the impact of principal forgiveness on mortgage default by comparing the relationship between pre- modification LTV and default on either side of the kink. We exploit the fact that the location of the kink varies from loan to loan based on the DTI, LTV, and the servicer’s LTV target.⁴

A number of researchers have examined the relationship between negative equity and mortgage default since the start of the housing crisis (Bajari et al., 2010; Bhutta et al., 2010; Fuster and Willen, 2015; Ghent and Kudlyak, 2011; Tracy and Wright, 2012; Haughwout et al., 2010). One strategy employed in the research is to use loan-level performance data (Bajari et al., 2010; Bhutta et al., 2010; Laufner, 2013) and exploit variation in negative equity arising from changes in state- or zip-code-level home price indexes. The major challenge inherited by these research designs is that the level of negative equity may not be exogenous. Variation in negative equity driven by local price changes may be associated with having neighbors who are increasingly underwater, living in an area with increasing vacancy rates, or low levels of home maintenance.

²HAMP PRA uses a series of specified mortgage modification steps to reduce mortgage payments until the borrower reaches a DTI ratio of 31%, the “affordability target”. The first step uses principal forgiveness to reduce the mortgage balance to achieve the affordability target, without reducing the borrower’s LTV below the servicer-specific target. If principal forgiveness to the LTV-target is insufficient to achieve the affordability target, the payment is decreased as needed until the affordability target is reached by lowering the mortgage rate, extending the mortgage term, and forbearing mortgage principal.

³Since the post-modification DTI is always 31%, increasing principal forgiveness coincides with decreased use of rate reduction, term extension, and forbearance, less generous modification steps.

⁴Some loans are subject to a second kink because their servicer caps principal forgiveness at 30% of the pre- modification principal balance. Below this 30% cap, increasing pre- modification LTV and DTI increases principal forgiveness; above this cap, it does not.

Variation in negative equity driven by initial down payment, mortgage terms, cash-out refinancing, or time of purchase may be associated with unobservable borrower characteristics.⁵

A separate line of research has considered the effects of mortgage modifications. Hembre (2014) estimates a structural model of mortgage default with data from “standard” HAMP, a separate part of the HAMP program we do not study that includes payment reduction but not principal forgiveness. Agarwal et al. (2012) exploits variation in HAMP program eligibility criteria to identify the effect of HAMP modifications, though this research does not focus on principal forgiveness in particular. Haughwout et al. (2010) and Agarwal et al. (2011a) look more directly at the role of principal forgiveness in modification performance by comparing the default rates on non-HAMP modifications with and without principal forgiveness. However, in the settings studied in previous research, it is not clear what unobservable criteria (including variables like pre-modification DTI and FICO that are observable in our data) affected who received principal forgiveness and how much they received. The impact of these unobservable factors on mortgage default or delinquency may be misidentified as coming from negative equity. Fuster and Willen (2015) provide evidence on the effects of payment reduction on mortgage default by evaluating borrowers with ARM loans, though not in the context of mortgage modifications or already-delinquent borrowers. This paper aims to overcome the omitted variable bias problems that are unavoidable when using local price variation to measure negative equity, as well as the selection issues inherent in studies of non-random mortgage modifications.

We find that principal forgiveness reduces subsequent rates of default, defined as

⁵Moreover, borrowers who have different levels of negative equity because they purchased at different times may be unobservably different. For example, there is evidence that income was less-stringently documented as home prices accelerated (Keys et al., 2010; Jiang et al., 2011), and that second homes comprised over half of the market near the height of the boom in areas with the most dramatic price swings (Haughwout et al., 2011).

90 day delinquency and consequent disqualification from the program. The cumulative default rate in our sample (the overall default rate thus far, including borrowers who have been in the sample for less than 2.5 years) is 16.4%; we estimate that it would have been 19.6% (95% CI: 18.1% to 20.8%) absent principal forgiveness. Among HAMP PRA participants in our sample, 3.1% default per quarter on average. Our estimates suggest that this default rate would have been 3.8% (95% confidence interval (CI): 3.5% to 4.1%) had these borrowers received modifications with no principal forgiveness but the same payment reduction (achieved instead through rate reduction, term extension, and principal forbearance). The average loan in the HAMP PRA sample received a 28% reduction in the mortgage balance. Our estimates indicate that principal forgiveness is more effective than is suggested by a naive interpretation of the relationship between post-modification LTV and default – neglecting the possibility that borrowers with higher LTVs may be unobservably better than borrowers with lower LTVs who require the same payment reduction.

The first cohorts of PRA modifications in our sample (those originated in the first half of 2011) had a cumulative default rate of 31% over the 9 to 10 quarters for which we have data; we estimate that it would have been 37% (95% CI: 34% to 40%) absent principal forgiveness. This 6 percentage point reduction in the default rate implies that principal forgiveness must be added to 17 mortgage modifications (in the amount specified by HAMP PRA) to avoid a single foreclosure over our sample period. Given the amount of principal forgiveness (averaging \$76,000 in the first cohorts), this point estimate implies that about \$1.3 million was written down per foreclosure avoided during the 9 to 10 quarter sample period.⁶ Given the government subsidy for principal forgive-

⁶Note that the actual cost per foreclosure avoided will be far less than this write-down amount, since writing down the principal balance is effectively costless for the share of mortgages that would have defaulted absent principal forgiveness. Calculating this actual cost requires a number of inputs we do not observe, including the probability of foreclosure over the lifetime of the loan absent principal forgiveness and the future timing of default or prepayment. Also note that while a mortgage written down to zero will not default, such a write down will reduce the number of defaults by less than one since the mortgage

ness in HAMP PRA (which averaged \$21,000 in the first cohorts), this point estimate implies that the government spent \$362,000 in subsidies per avoided foreclosure during the 9 to 10 quarter sample period. By this standard, the program is less cost-effective in avoiding foreclosures than “standard” HAMP without principal forgiveness, as estimated by the structural model in Hembre (2014).⁷ The relatively low counterfactual default rate from the payment-reduction program and the modest improvement from principal forgiveness are consistent with Eberly and Krishnamurthy (2014), who use a model to argue that principal forgiveness is not the most cost-efficient way to avoid default.

Our results are robust to a variety of specifications. The pre- modification LTV at the kink varies from borrower to borrower based on pre- modification DTI; as a result, we can control non-parametrically for pre- modification LTV. Since servicers differ in their policies, we can obtain separate estimates for each kink. In addition, we can compare otherwise identical borrowers who received different amounts of principal forgiveness because they had different servicers to obtain a “between” estimate of the effect of principal forgiveness, controlling non-parametrically for the interaction of pre-modification LTV and pre- modification DTI. All yield similar estimates. By contrast, estimates using two different “placebo samples” of loans that were ineligible for principal forgiveness show no such pattern. A “placebo treatment” shows that distance from a hypothetical kink from the policy of a servicer other than the borrower’s actual servicer also shows no such pattern.

might not have defaulted absent the write-down.

⁷Hembre (2014) estimates a \$41,000 five-year government cost per foreclosure avoided in “standard” HAMP.

2.2 HAMP Structure and Identification

The Home Affordable Modification Program (HAMP) was announced in February 2009 under the authority of the Troubled Asset Relief Program (TARP). HAMP uses TARP funds to subsidize servicers and lenders to modify the terms of mortgage loans according to the rules of the program. The HAMP program aimed to combat two barriers to mortgage modifications. First, foreclosures may carry externalities which are not considered by servicers and investors. Second, informational asymmetries, legal barriers, and coordination problems may prevent servicers and investors from modifying mortgages even when it would be in investors' interests. (Agarwal et al., 2011b; Adelino et al., 2013) HAMP created a subsidized and focal modification to overcome these problems.

When borrowers become 60-days delinquent, HAMP servicers are required to send them a letter with information about HAMP.⁸ To be eligible for the HAMP program, borrowers must have a debt-to-income (DTI) ratio over 31%, live in the home, and have an unpaid balance below \$729,750.⁹ When borrowers apply for HAMP, they provide information about their income, which is used to determine their DTI. DTI measures the fraction of the borrower's pre-tax income that goes to monthly first-lien mortgage payments, real estate taxes, homeowner's insurance, and condominium or homeowner's association dues. An automatic appraisal system calculates the borrower's home value, which is used to determine the loan-to-value (LTV) ratio, the balance on

⁸Non-delinquent borrowers may also apply for HAMP, and are eligible for the program if their default is deemed imminent. Though many servicers use an imminent default calculator similar in structure to the default model embedded in the HAMP NPV test, ultimately imminent default is determined by the servicer for their and their investors' portfolios.

⁹However, larger balances are allowed for multi-family properties if the borrower lives in one of the units. In June 2012, HAMP eligibility was expanded to non-owner occupiers, borrowers with lower DTI ratios, and borrowers who could not achieve a 31% DTI ratio using the standard HAMP modification steps. The modification granted by the expanded program (HAMP Tier 2) is different than in the original program and does not generate the kink employed in our identification strategy, even when principal forgiveness is included. We exclude PRA recipients in Tier 2 from our sample.

the first mortgage divided by the home value.

Two modifications are commonly offered under HAMP: ‘standard’ HAMP and HAMP PRA. Standard HAMP is similar to HAMP PRA except that it does not include principal forgiveness. Servicers use an NPV model to compare the expected discounted cash flows lenders would receive with and without a modification.¹⁰ To encourage participation in HAMP, the government provides subsidies to participating lenders. Not all HAMP-participating servicers participate in HAMP PRA and some loans are ineligible for HAMP PRA (e.g., loans guaranteed by Fannie Mae and Freddie Mac, and mortgage investors whose contracts specifically forbid or limit principal forgiveness).

Once borrowers are offered and accept the modification, they are given a three-month trial period during which they must stay current on their mortgage and produce any required documentation.¹¹ The mortgage modification becomes permanent after the trial period, at which point delinquency or foreclosure proceedings are terminated. If borrowers become more than 90 days delinquent on a permanent modification, they are dropped from the program (and our data).

¹⁰The NPV model estimates a default probability, prepayment rate, and recovery rate based on the borrowers’ pre- and post-modification DTI and LTV, their FICO score and delinquency at the time of modification, their geography, and other variables. Updated FICO scores are pulled from credit bureaus. Government subsidies are included in lenders’ NPV calculations. Servicers typically offer borrowers the option that yields the highest NPV to the lender, though they may use other objective criteria (e.g., do a HAMP PRA modification if it is better than no modification even if ‘standard’ HAMP yields an even higher NPV).

While there will be selection into ‘standard’ HAMP, HAMP PRA, and no modification based on the NPV model, the structure of the model is known to the econometricians (and is publicly available at www.hmpadmin.com) as are the loan-level variables used to calculate the NPV for each borrower who receives a HAMP PRA modification. As a result, any selection stemming from the NPV model can be corrected for explicitly.

¹¹If borrowers fail to produce this documentation or go delinquent during this period, they fail out of the trial modification. At this point, the mortgage reverts to its pre- modification terms and delinquency or foreclosure proceedings can continue; the borrower may also be evaluated for a non-HAMP modification.

2.2.1 HAMP PRA

The HAMP Principal Reduction Alternative (PRA) modification is designed to bring the borrower's mortgage payment to an affordable level – to a post-modification DTI of 31% – in a way that prioritizes principal forgiveness.¹² Servicers set their own LTV targets. Servicers covering roughly 85% of our sample use a 115% LTV target, and the remaining servicers use a 100% LTV target.¹³

Payment reduction is achieved by forgiving mortgage principal by the minimum amount necessary to achieve either the affordability target (31% DTI) or the servicer's LTV target. Servicers with an LTV target of 100% also apply a 30% cap on the amount of principal forgiven as a share of the principal balance. If this principal forgiveness is sufficient to reach the affordability target, there are no additional changes to mortgage terms. If this principal forgiveness is insufficient to reach the affordability target, the modification achieves further payment reduction using rate reduction and term extension. The interest rate is reduced as needed to reach 31% DTI or to 2%, whichever comes first; then the mortgage term is lengthened as needed to reach 31% DTI or 40 years, whichever comes first; then, principal is forborne as needed to reach 31% DTI.

We use Table 2.1 to illustrate the structure of the PRA modification with a hypothetical example. The borrower in this example has a mortgage balance of \$150,000 with 25 years (300 months) remaining on a 6% fixed-rate mortgage, so that their pre-

¹²DTI is the proportion of income needed for the mortgage payment and other fixed housing expenses such as real estate taxes, homeowner association fees and insurance. DTI is the sum of the mortgage DTI (MDTI) and the fixed DTI (FDTI), where the former is the proportion of income needed to make the mortgage payment and the latter is the proportion of income needed to pay real estate taxes, insurance, and other fixed housing expenses, which do not vary with the mortgage terms. Since the mortgage modification does not change the fixed portion of the borrower's monthly payments, the 31% DTI target must be achieved exclusively by reducing the mortgage DTI. As a result, the mortgage DTI target is 31% minus the pre- modification fixed DTI.

¹³While many servicers did not participate in PRA initially, most non-GSE HAMP modifications are done by servicers who now participate in PRA. We have excluded several PRA-participating servicers with volume so low we could not ascertain their LTV target with certainty, and two large servicers who use principal-reduction allocation methods that do not generate the kink we exploit for identification.

modification monthly principal and interest (P&I) payment is \$966. They must pay an additional \$500 per month for property taxes and insurance, so that the borrower's monthly total pre- modification payment is \$1,466. The borrower's monthly income is assumed to be \$3,500, which implies that their total pre- modification DTI is $42\% = (\$966 + \$500) / \$3,500$; to reach the 31% DTI target, the monthly P&I payment must be reduced from \$966 to \$585.

In the first column of Table 2.1, this borrower's home value is assumed to be \$100,000, so that the pre- modification LTV = $150\% = \$150,000 / \$100,000$; as a result, they would need \$35,000 in principal forgiveness to bring the balance down to \$115,000 and reach the servicer's LTV target (115%). Without changing the borrower's interest rate or mortgage term, lowering the balance to \$115,000 would bring their monthly payment to \$764 P&I + \$500 taxes = \$1,264. Since principal forgiveness alone is insufficient to reach the DTI target, the interest rate of the loan must also be lowered from 6% to 3.65%, bringing the monthly P&I payment on the new \$115,000 balance to \$585 in order to reach the DTI target ($31\% = (\$585 + \$500) / \$3,500$).

These modification steps imply that post-modification LTV – and consequently the amount of principal forgiveness – will depend on pre- modification LTV, the servicer's LTV target, the pre- modification mortgage DTI (pre- modification MDTI), and the mortgage DTI target (MDTI target). We define the principal forgiveness ratio (PF) as:

$$\begin{aligned}
 \text{PF} &\equiv \frac{\text{pre- modification LTV}}{\text{post-modification LTV}} - 1 & (2.1) \\
 &= \max \left(0, \min \left(\frac{\text{pre- modification LTV}}{\text{target LTV}} - 1, \frac{\text{pre- modification MDTI}}{\text{target MDTI}} - 1 \right) \right) \\
 &= \max (0, \min (\text{PF}_{\text{LTV}}, \text{PF}_{\text{DTI}}))
 \end{aligned}$$

where

$$PF_{LTV} \equiv \frac{\text{pre- modification LTV}}{\text{target LTV}} - 1; PF_{DTI} \equiv \frac{\text{pre- modification MDTI}}{\text{target MDTI}} - 1. \quad (2.2)$$

Principal forgiveness is the minimum of the amounts needed to reach the LTV and DTI targets. For loans with a pre- modification LTV above the servicer's target:

$$\ln(1 + PF) = \min(\ln(1 + PF_{LTV}), \ln(1 + PF_{DTI})). \quad (2.3)$$

Bringing the example from the first column of Table 2.1 into equations 2.1-2.3, the amount of principal forgiveness implied by the LTV target ($PF_{LTV} = 150\%/115\% - 1 = 30\%$) is lower than the amount implied by the DTI target ($PF_{LTV} = \$966/\$585 - 1 = 65\%$), so principal forgiveness is determined by the LTV target ($\ln(1 + PF) = 0.26 = \ln(1 + 0.30)$).

2.2.2 Identification

The structure of the HAMP PRA modification generates kinks in the relationship between pre- modification LTV and principal forgiveness. We exploit these kinks for identification.

For loans with sufficiently low pre- modification LTV relative to pre- modification DTI, reducing the borrower's LTV to its target level is insufficient to reach the

¹⁴For loans with servicers who have a LTV target of 100%, principal forgiveness is limited to 30% of the initial mortgage balance. In this case, $PF \equiv 1/(1 - 30\%) - 1 = 10/7 - 1 = 3/7$. For this sample, the principal forgiveness amount is determined as follows:

$$\begin{aligned} PF &\equiv \frac{\text{pre- modification LTV}}{\text{post-modification LTV}} - 1 \\ &= \max\left(0, \min\left(\frac{\text{pre- modification LTV}}{\text{target LTV}}, \frac{\text{pre- modification MDTI}}{\text{target MDTI}}, 10/7\right) - 1\right). \end{aligned}$$

Table 2.1: Example: Principal Forgiveness Calculations

Unpaid principal balance	\$150,000			
Mortgage rate	6.00%			
Mortgage term (months)	300			
Principal and interest (P&I) payment	\$966			
Monthly taxes and insurance	\$500			
Total monthly mortgage payment	\$1,466			
Gross monthly income	\$3,500			
pre- modification Debt-to-income (DTI) ratio	42%			
P&I payment at target	\$585			

Modification Outcomes for Borrowers on Either Side of Kink				
	LTV target binds		DTI target binds	
	(a)	(b)	(c)	(d)
Home value	\$100,000	\$99,000	\$76,000	\$75,000
pre- modification LTV	150%	152%	197%	200%
PF _{LTV} (\$)	\$35,000	\$36,150	\$62,600	\$63,750
PF _{LTV} (%) (see eq. 2.2)	30%	32%	72%	74%
PF _{DTI} (\$)	\$59,204	\$59,204	\$59,204	\$59,204
PF _{DTI} (%) (see eq. 2.2)	35%	35%	35%	35%
LTV at kink (see eq. 2.4)	190%	190%	190%	190%
$Min(PF_{LTV}, PF_{DTI})$ (\$)	\$35,000	\$36,150	\$59,204	\$59,204
$Min(PF_{LTV}, PF_{DTI})$ (%) (see eq. 2.1)	30%	32%	35%	35%
$ln(1 + PF)$ (see eq. 2.3)	0.27	0.28	0.30	0.30
Modified mortgage rate	3.56%	3.65%	6.00%	6.00%
Modified LTV	115%	115%	119%	121%

affordability target of 31% DTI. In this range, principal forgiveness is increasing (and other, less generous modification steps are decreasing) in pre- modification LTV; post-modification LTV reaches the LTV target and is therefore unaffected by pre- modification LTV. This situation is illustrated in either panel of Figure 2.1, to the left of the circle. For loans with sufficiently high pre- modification LTV relative to pre- modification DTI, the affordability target of 31% DTI will be reached using principal forgiveness alone; the constraint provided by the LTV target does not bind. Principal forgiveness, mortgage rate, and term are all unaffected by pre- modification LTV in this range; post-modification LTV is increasing in pre- modification LTV. This situation is illustrated in either panel of Figure 2.1, to the right of the circle.

This identification strategy can be shown by varying the home value (and con-

sequently the pre- modification LTV) in the example from Table 2.1. Columns 1 and 2 show home values (\$100,000 and \$99,000) that are sufficiently high so that principal forgiveness is limited by the LTV target. In this range, increasing LTV slightly (by lowering the home value) increases the amount of principal forgiveness necessary to reach the 115% LTV target. When the home value is \$100,000, \$35,000 in principal forgiveness brings the mortgage balance from \$150,000 to \$115,000 ($\$115,000/\$100,000 = 115\%$); when the home value is \$99,000, \$36,150 in principal forgiveness brings the mortgage balance to \$113,850 ($\$113,850/\$99,000 = 115\%$). Lowering the home value by \$1,000 (and consequently increasing the pre- modification LTV) increases the amount of principal forgiveness by \$1,150. However, the interest rate on the modification is correspondingly higher (3.56% vs. 3.65%) so that the monthly P&I payment remains constant at \$585. Columns 3 and 4 show home values (\$76,000 and \$75,000) that are sufficiently low so that principal forgiveness is limited by the DTI target. In this range, the terms of the mortgage modification are unaffected by marginal change in home value. The modification reaches the monthly P&I payment target (\$585) by providing \$59,204 in principal forgiveness to bring the balance from \$150,000 to \$90,796; the interest rate remains at the pre- modification rate (6%). The post-modification LTV will remain above the 115% target.

Principal forgiveness is a kinked function of the borrower's pre- modification LTV. The kink occurs at LTV^* , the border between the low-LTV range where the amount of forgiveness varies with pre- modification LTV (as in columns 1 and 2 from Table 2.1) and the high-LTV range where it does not (as in columns 3 and 4). At this point, the amounts of forgiveness needed to reach the LTV and DTI targets are equal, equating the two terms in the minimum function in equation 2.3:

$$LTV^* = \text{target LTV} \times \frac{\text{pre- modification MDTI}}{\text{target MDTI}} \quad (2.4)$$

In the example from Table 2.1, $LTV^* = 115\% \times \$966 / \$585 = 190\%$, which is reached when the home value is \$79,000 (\$150,000 balance/190%). Varying the borrower's income will shift their target MDTI and consequently LTV^* . In Figure 2.1, the left panel shows a moderate pre- modification MDTI while the right panel shows a higher pre- modification MDTI; given equation 2.4, the kink (circled in both panels) is at a higher pre- modification LTV in the right panel. In this setting, it is straightforward to calculate the distance from the kink, the difference between pre- modification LTV and LTV^* :

$$\begin{aligned} \text{distance from kink} &\equiv \frac{\text{pre- modification LTV}}{LTV^*} - 1; \\ \ln(1 + \text{distance from kink}) &= \ln(1 + PF_{LTV}) - \ln(1 + PF_{DTI}). \end{aligned} \quad (2.5)$$

We can also understand marginal effects around the kink by taking the derivative of equation 2.3 with respect to pre- modification LTV:

$$\begin{aligned} \frac{d \ln(1 + PF)}{d \ln(\text{pre- modification LTV})} &= 1 && \text{if pre- modification LTV} < LTV^*; \\ &= 0 && \text{if pre- modification LTV} > LTV^*. \end{aligned} \quad (2.6)$$

A second kink is present at the 30% principal forgiveness cap for servicers that apply this cap. The cap lowers LTV^* in equation (5) for borrowers whose MDTI and pre- modification LTV both exceed their target by more than 30% - in other words, for high-DTI, high-LTV borrowers. Below the LTV^* implied by this cap, increasing pre- modification LTV increases principal forgiveness; above this point, the modification is unchanged by increasing pre- modification LTV.

The kinked structure of the problem allows us to examine the impact of principal forgiveness – or equivalently, post-modification LTV – while controlling separately for

pre- modification LTV, pre- modification MDTI, target LTV, and target MDTI. This suggests the following basic regression to predict re-default:

$$\begin{aligned} \text{Pr(Default)} = f(\alpha &+ \beta_F \ln(1 + \text{PF}) \\ &+ \beta_{\text{LTV}}(\ln(1 + \text{PF}_{\text{LTV}})) + \beta_{\text{DTI}}(\ln(1 + \text{PF}_{\text{DTI}})) + \beta_X X + \epsilon) \end{aligned} \quad (2.7)$$

The forgiveness term in the first row of equation (2.7) is the minimum of the second and third terms. The regression examines the impact of principal forgiveness while controlling separately for the two terms in the min function that determine it.¹⁵ The identifying assumption here is that this minimum of the affordability term and the negative equity term has no independent impact on default except insofar as it determines the amount of principal forgiveness the borrower receives. It is straightforward to allow for an interaction of the LTV and DTI, so long as this interaction doesn't take form of a minimum.

Figure 2.1 shows the relationship between pre- modification LTV and post- modification LTV for borrowers with moderate (left panel) and high (right panel) pre- modification DTI. These figures can be used to visualize a sequence of increasingly flexible identification strategies. The most restrictive identification strategy can be visualized with a single panel, such as the one in the top left. This strategy uses borrowers with the same pre- modification DTI and servicer policy and compares the relationship between pre- modification LTV and default on either side of the kink. Linear – but not flexible, non-parametric – LTV controls are possible because pre- modification LTV perfectly predicts principal forgiveness. As a result, there is no way to separate non-linear LTV effects from principal forgiveness.

A more flexible identification strategy combines the left and right panels of Fig-

¹⁵Equivalently in the kink framework, β_{LTV} and β_{DTI} control for the borrower's position relative to the kink, and β_{PR} gives the change in the slope at the kink point. The change in the reaction function at the kink point must be divided by the change in the derivative of the treatment function at the kink point, which in this case is one.

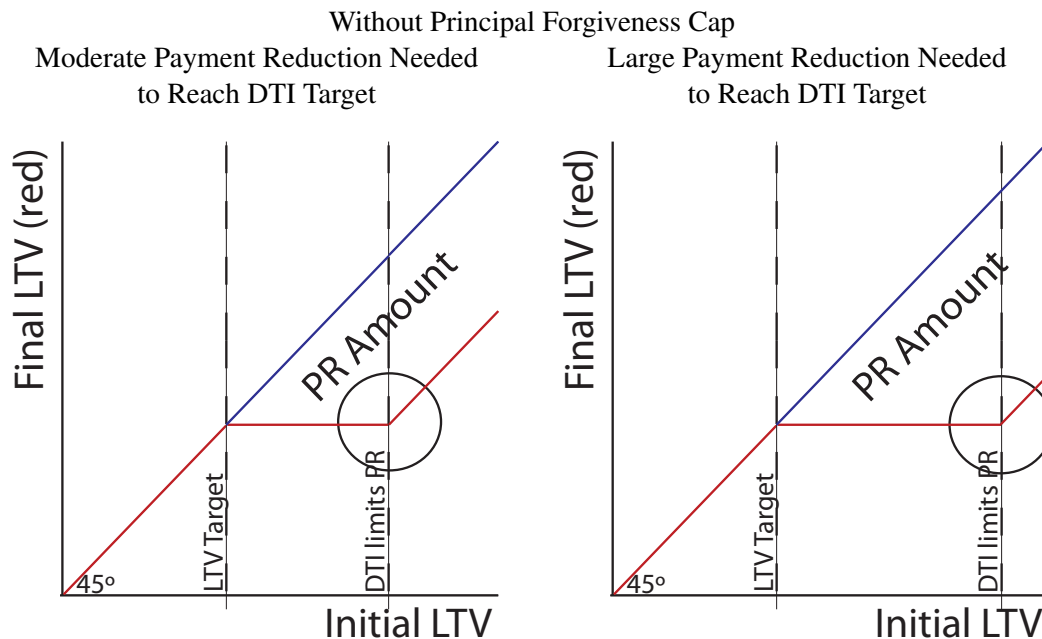


Figure 2.1: HAMP PRA Identification

Figure 2.1. This identification strategy includes all borrowers with the same servicer LTV target (and no servicer forgiveness cap), regardless of pre- modification DTI. Because the kink occurs in different locations for borrowers with different pre- modification DTI, it is possible to include flexible, non-parametric controls for pre- modification LTV and pre- modification DTI. A parametric interaction term for pre- modification LTV and pre- modification DTI could also be included. This specification allows us to separate non-linear LTV and DTI effects – but not non-linear LTV-DTI interactions – from principal forgiveness. This “within” (within-servicer) identification strategy is employed in the third column of Table 2.5 for servicers with a 115% LTV target, and in the fourth column of Table 2.5 for servicers with a 100% LTV target and a 30% forgiveness cap.

An even more flexible identification strategy exploits the fact that servicers with different LTV targets differ in principal forgiveness even for borrowers with the same pre- modification LTV and pre- modification DTI. In other words, the location of the

kinks in Figure 2.1 will differ by servicer. By comparing servicers with different LTV targets, it is possible to estimate the relationship between principal forgiveness and default with non-parametric controls for the interaction of pre- modification LTV and pre- modification DTI. This “between” (between-servicer) identification strategy is employed in the second column of Table 2.5.

2.3 Data

Data come primarily from HAMP administrative “loan setup” files, which record modification characteristics and performance. Additional data come from “NPV run” files, which record variables used when evaluating the net present value of modifications to the lender.¹⁶ We also use MSA-level unemployment rates from the Bureau of Labor Statistics and zip-code level median home price measures from Zillow. (We use MSA-level median home price measures from Zillow for zip-code months for which the zip-code level data were unavailable.) We examine new permanent HAMP modifications on non-GSE loans enrolled in 2011, 2012, and the first half of 2013. (GSE loans are mortgages backed by Fannie Mae or Freddie Mac. These loans are ineligible for HAMP PRA.)

HAMP PRA officially launched in October 2010, but borrowers must complete a 3-month trial period before becoming eligible for a “permanent” modification, which entitles the borrower, servicer, and investor to government subsidies, and which permanently alters the borrower’s mortgage terms. We therefore begin our sample in January 2011. We focus on modifications that complete the trial period and become permanent because these data are checked for internal consistency and randomly audited as the subsidy payments are set up. Data on loans that fail out of the trial period are not

¹⁶Not all records in the loan setup files have matching NPV run files; when we include variables from the loan set-up file in our regressions, some observations are dropped.

subject to this level of scrutiny, and can be incomplete and unreliable. About 10% of the trial modifications originated during our sample period failed to become permanent; roughly two-thirds of this fall-out can be attributed to nonpayment. Because we cannot consistently decipher whether the failure to submit documentation reflects ineligibility or default, we do not consider the impact of principal forgiveness on re-default during the trial period of a modification; results are conditional on the modification's survival to three months.

We use falling 90 days (or more) delinquent – and consequent disqualification from HAMP – as our measure of default.¹⁷ This is similar to the default measure used by Bhutta et al. (2010). We have no subsequent performance data on borrowers who drop out of HAMP.

Our analysis is performed at a quarterly frequency, examining the default hazard in each calendar quarter for cohorts of loans that became permanent in each calendar quarter.¹⁸ Because at least 90 days must elapse before a borrower is disqualified from HAMP, it is virtually impossible to exit HAMP in the same quarter that a permanent modification begins. As a result, we include default data from the second quarter of 2011 through the third quarter of 2013, and we begin monitoring performance in the second quarter of each borrower's HAMP tenure. The first cohort of modifications (those that became permanent in the first quarter of 2011) has ten quarters of default data (from the second quarter of 2011 through the third quarter of 2013); the most recent cohort of

¹⁷After being disqualified from HAMP, the borrower may be evaluated for an additional non-HAMP modification, or foreclosure proceedings may be initiated. We do not have loan-level performance data following disqualification, so the eventual disposition of disqualified PRA HAMP modifications is unobserved. We refer to falling out of the program as “default” or “re-default”, but borrowers falling out of HAMP do not necessarily permanently default – their mortgage could be repaid in full outside of HAMP. However, it is worth noting that falling out of HAMP PRA is punitive – the borrower loses any principal forgiveness that has not yet been earned. Because of the earned principal forgiveness feature, HAMP PRA is more generous than nearly all modifications available to borrowers, so a borrower who fails out of HAMP PRA is unlikely to remain in their home as a homeowner without a material improvement in their financial position.

¹⁸Default is recorded in the quarter in which the loan first becomes 90 days delinquent, namely 90 days after the last payment the borrower was scheduled to make but did not.

modifications (those that became permanent in the second quarter of 2013) has only one quarter of default data (the third quarter of 2013).

In the first quarter of 2011, approximately 12 million mortgage borrowers were underwater. About 6 percent of borrowers with substantial negative equity were in some stage of default at that time (CoreLogic (2013), Figure 6). Many of these borrowers would be ineligible for HAMP because they have DTI ratios below 31 percent, and not all eligible borrowers apply for HAMP. During the enrollment period in our sample, 632,653 new permanent modifications were started in HAMP. Of these, 363,863 were non-GSE loans, and therefore eligible for HAMP PRA. Of the non-GSE loans, 240,492 had LTV over 115 percent, and of these, 212,103 were with servicers participating in PRA. (Section 2.6.1 shows the number of standard HAMP and HAMP PRA loans originated in each month.) During our sample period, 108,785 modifications included HAMP PRA principal forgiveness amounting to over \$8 billion. From the beginning of the program through the end of our sample period (2013:Q3), 1.4 million permanent first-lien HAMP modifications were granted. The cumulative 10-quarter default rate for the cohort of HAMP loans modified in 2009 averaged 33%. The 10-quarter cumulative default rate for the cohort of HAMP loans modified in 2011 was 29%.

We encounter extreme values in the data, some of which likely reflect data entry errors rather than true mortgage characteristics.¹⁹ Our sample consists of 45,513 loans, and \$3.8 billion in principal forgiveness. Since the prepayment rate for HAMP PRA loans was extremely low (less than 0.5 percent in our sample), we lack the power to

¹⁹On these grounds, we exclude borrowers with initial DTI ratios (including taxes, HOA fees, and insurance) over 100% and initial LTV ratios over 240%. We lose about 21 thousand loans due to these restrictions. We drop loans for which either the mortgage rate, term, or unpaid balance is recorded as zero, or where servicers' PRA policies could not be determined because they had very few PRA loans. We also drop loans that received principal forgiveness through a program other than HAMP PRA; these loans were not required to follow a specific formula. We drop one large and one medium-sized servicer who use principal forgiveness allocation methods that do not generate the kink we exploit for identification; loans from these two servicers comprise the majority of dropped loans. The dropped population comprised about 60% of the full sample of PRA recipients who enrolled during the sample period. For these reasons, our total loan counts will not match publicly-available information on the HAMP PRA program.

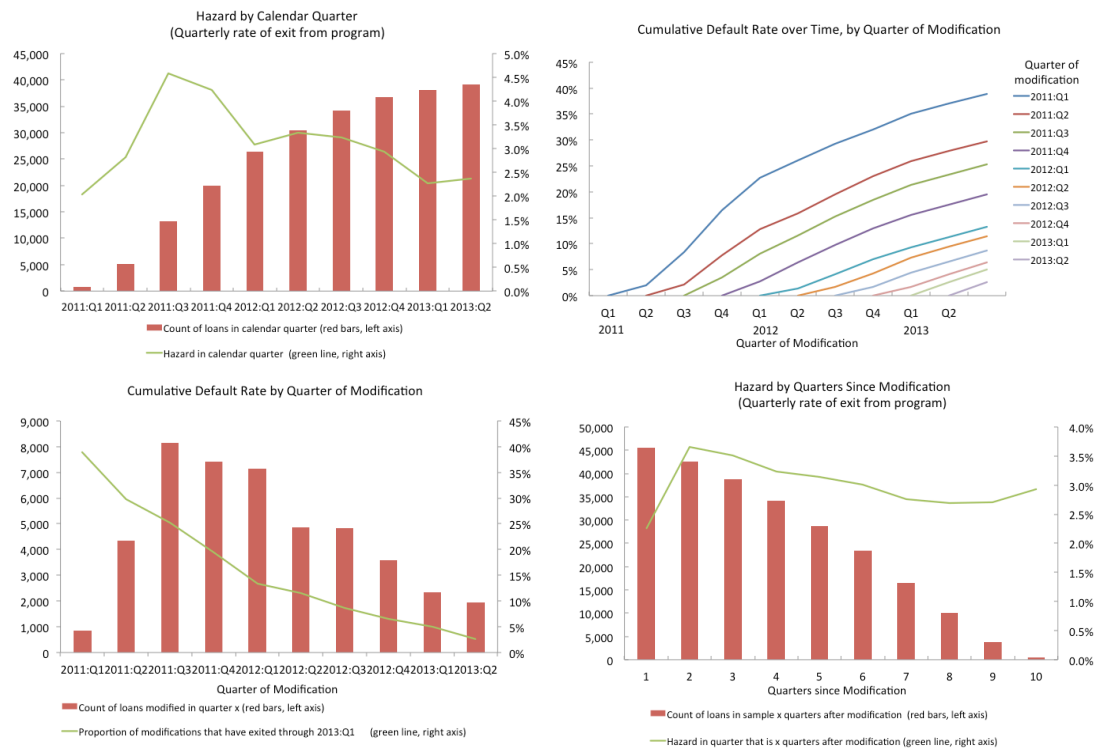


Figure 2.2: Loan Count Statistics

investigate the effect of principal forgiveness on prepayment.

Table 2.2 shows that the median home value in the sample is \$180,000 and the median pre- modification mortgage balance is \$292,000, though there is substantial variation. Table 2.3 shows that HAMP PRA reduces the median DTI from 44% to 31% and reduces median LTV from 159% to 115%, a 30% principal forgiveness on average. Figure 2.2 (lower left corner) shows that the number of new modifications peaked in the third quarter of 2011 at just over 8,000 for the quarter and has fallen consistently since then to below 2,000 in the most recent quarter. The average monthly mortgage payment is \$2,200, of which \$1,800 goes toward principal and interest. For the median loan, principal and interest payments comprise 83% of the total mortgage payment. For the 10th and 90th percentile loans, principal and interest payments comprise 78% and

Table 2.2: Summary Statistics About Loans and Borrowers

	N	Median	Mean	St. Dev.	Min	Max
Balance pre- mod ('000s)	45,513	\$292	\$324	\$173	\$18	\$1,279
Home value ('000s)	45,513	\$180	\$205	\$118	\$10	\$856
Gross monthly income ('000s)	45,513	\$4.5	\$4.9	\$2.4	\$0.6	\$22.2
Total Mortgage Payment ('000s)	45,513	\$2.0	\$2.2	\$1.1	\$0.3	\$9.5
Principal & Interest Payment ('000s)	45,513	\$1.6	\$1.8	\$0.9	\$0.2	\$9.0
FICO	41,833	559	568	69	250	839

The mortgage balance includes accrued past unpaid interest; the home value is the assessed home value from the servicer's automated valuation model (AVM) at time of modification, or a broker's price opinion (BPO) or appraisal, where an AVM is unavailable. Monthly mortgage payment includes mortgage principal and interest; monthly total payment includes mortgage principal and interest, as well as homeowners' insurance premiums and property taxes. Gross income is the borrower's monthly pre-tax eligible income, excluding temporary sources such as unemployment insurance benefits or self-employment income from an irregular source. The sample includes most borrowers who received some amount of principal forgiveness through the HAMP PRA program between January 1, 2011 and June 30, 2012. The sample excludes borrowers who received only unsubsidized principal forgiveness (which may be allocated under a different framework than PRA) and borrowers whose servicers' PRA policies either could not be imputed or did not generate the kink exploited for this analysis.

Source: Authors' analysis of HAMP data.

90% of total mortgage payments, respectively.

Figure 2.2 shows that default rates have been relatively constant as modifications age, with a hazard of about 3% per quarter between the fourth and tenth quarters after modification. There is some indication that default rates have fallen with calendar time – from a peak in the quarterly default hazard in the fourth quarter of 2011 at 4.6% to 2.4% in the third quarter of 2013 – though the relationship is not monotonic.

2.4 Results

2.4.1 Basic Results

Table 2.4 shows the results of a hazard regression to predict quarterly entry into default using a logit functional form, as shown in Equation 2.7. Our independent vari-

Table 2.3: Summary Statistics About Modification

	N	Median	Mean	St. Dev.	Min	Max
Total DTI pre- mod	45,513	44.2%	47.0%	12.3%	24.0%	100.0%
Total DTI post-mod	45,513	31.0%	31.0%	0.4%	12.4%	33.0%
Total payment reduction	45,513	29.8%	30.0%	16.0%	0.0%	69.0%
LTV before modification	45,513	158.8%	164.2%	33.5%	109.8%	240.0%
LTV after modification	45,513	115.0%	121.2%	16.1%	100.0%	237.7%
Principal forgiveness	45,513	28.2%	28.9%	17.4%	0.0%	73.5%
Rate pre- mod	45,513	6.375%	6.3%	2.0%	0.8%	15.1%
Rate post-mod	45,513	3.0%	3.9%	2.1%	1.0%	15.0%
Term pre- mod (months)	45,513	305	317	60	1	541
Term post-mod (months)	45,513	301	333	76	12	541

Mortgage debt-to-income (DTI) is the ratio of the borrower's monthly mortgage payment (principal and interest) to gross income. Total DTI is the ratio of the total monthly payment (principal, interest, homeowners insurance, and property taxes) to gross income. Loan-to-value (LTV) is the ratio of the mortgage balance to the home value.

Source: Authors' analysis of HAMP data

able of interest is the the natural log of the amount of principal forgiveness (PF, predicted by equations 2.1 and 2.2). Errors are clustered by MSA. The first column includes linear controls for the natural log of the principal forgiveness amount predicted by the borrower's LTV and the natural log of the principal forgiveness amount predicted by DTI (together, these two variables control for the location of the kink), an indicator variable for whether the servicer uses an LTV target of 115% (as opposed to 100%), and 10 dummy variables indicating the number of quarters since modification. The second column adds 10 dummy variables indicating the modification's cohort quarter, servicer dummies, and borrower's pre- modification total DTI. The third column adds an interaction between the natural log of pre- modification LTV and the natural log of pre- modification mortgage DTI. The fourth column adds additional controls including the 4 quarter change in the unemployment rate at the the MSA-level, the zip-code level percent change in median home price from modification through the current quarter and from origination through modification, origination year dummies, remaining term

length, state dummies, the borrower's FICO, NPV test results (for standard HAMP and PRA, in natural logs), the natural log of gross monthly income, the natural log of pre-modification principal balance, the trial length (in months), the square of the trial length, and dummy variables indicating ARM and investor-owned loans. The final column adds 10-percentage-point bins for each of the principal forgiveness predicted by LTV (in logs) and the principal forgiveness predicted by DTI (in logs).

Table 2.4: Quarterly Hazard: Impact of Principal Forgiveness on Program Exit

Dep. Var.	Quarterly Exit Rate					
$\ln(1 + PF)$	-0.851 *** (0.148)	-0.538 *** (0.137)	-0.611 *** (0.157)	-0.844 *** (0.165)	-0.908 *** (0.316)	
$\ln(1 + PF_{LTV})$	0.380 *** (0.137)	0.225 * (0.129)	0.107 (0.128)	0.759 *** (0.163)	-0.684 (0.55)	
$\ln(1 + PF_{DTI})$	-1.072 *** (0.091)	0.418 *** (0.063)	0.313 *** (0.120)	0.143 (0.149)	2.278 *** (0.776)	
Dummy for LTV target = 115 percent	YES	YES	YES	YES	YES	YES
Quarters of observation controls	YES	YES	YES	YES	YES	YES
Quarter cohort and servicer dummies	NO	YES	YES	YES	YES	YES
DTI before modification	NO	YES	YES	YES	YES	YES
Interaction variable	NO	NO	YES	YES	YES	YES
Other controls	NO	NO	NO	YES	YES	YES
10-ppt LTV and DTI bins	NO	NO	NO	NO	NO	YES
Observations	244,132	244,132	244,132	160,371	159,826	
Loans	45,513	45,513	45,513	29631	29522	
R^2	0.0289	0.0520	0.0520	0.0815	0.0827	

Each observation refers to a loan in a calendar quarter; observations are included on loans that have not exited from the program to date and for which data is available for the entire quarter. Results from a hazard for quarterly program exit, where the hazard is specified as a logit; coefficients are shown. "Other Controls" includes FICO score, the 4-quarter change in the MSA-level unemployment rate, zip-level percent changes in HPI from modification through the current quarter and from origination to modification, modification year dummies, adjustable rate mortgage dummy, investor-owned mortgage dummy, In income, In pre- modification mortgage balance, length of trial modification (linear and squared), In NPV of HAMP modification over no modification, In NPV of HAMP PRA modification over no modification, and a dummy for whether the standard HAMP modification had a higher NPV than the HAMP PRA modification. Standard errors are clustered by MSA.

The coefficient on principal forgiveness varies between -0.54 and -0.91 and is statistically significant. The estimate from the first column implies that on a baseline re-default hazard of 3.1%, a 10 percent principal forgiveness would reduce the re-default hazard by 0.2 to 0.3 percentage points (from 3.1% to 2.8% or 2.9%). In the final two columns, we include zip-level measures of the percent change in median home price from origination through modification and modification through the observation quarter, along with origination year dummies. While the estimate on the coefficient associated with the price change since modification is statistically insignificant, it has the expected negative sign. We find some evidence that loans with higher origination loan-to-value ratios default at a higher rate post-modification. The coefficient on the change in home price from origination through modification is positive and statistically significant, with a value of 0.60 and a standard error of 0.14. The coefficient on the change in home price from modification through the observation quarter is -0.61 with a standard error of 0.41. Controlling for origination year, current unpaid balance, and term at modification, loans that experienced higher home price growth to achieve a given LTV likely started with higher initial LTVs.

Figure 2.3 provides a graphical representation of the changing relationship between pre- modification LTV and default around the kink. This figure plots the dummy variable coefficients from a regression that mimics equation 2.7, replacing the $\ln(1+PF)$ and $\ln(1 + PF_{LTV})$ variables with dummy variables for a series of bins grouped by log distance from the kink ($\ln(1+PF_{LTV}) - \ln(1+1 + PF_{DTI})$) as shown in equation 2.5 in bins of size 0.1. Results are normalized by omitting the bin at the kink, so that the plotted values indicate the difference between the default hazard for each bin and the reference bin. Controls are as specified in the second column of Table 2.4 and the sample is limited to loans subject to a 115% LTV target. Given the other controls, varying distance from the kink is equivalent to varying pre- modification LTV.

Figure 2.3 shows a marked change in the relationship between pre- modification LTV and default around the kink. To the left of the kink, default is falling with pre- modification LTV. In this range, increasing pre- modification LTV has no effect on post- modification LTV as increasing pre- modification LTV leads to one-for-one increases in the generosity of principal forgiveness. The negative slope to the left of the kink shows that increasing pre- modification LTV (or something correlated with it) reduces the default hazard, even after controlling for post-modification LTV. This will lead our causal estimates of the effect of principal to differ from naive estimates that infer causality from the correlation between LTV and default. The source of this divergence is a matter for speculation. One possibility is that low-LTV loans have higher second liens or other unobserved non-housing expenses that increase their probability of default. That could result from low LTV loans without such expenses choosing not to apply for HAMP. Another possibility is that pre- modification LTV could be directly relevant in the event of default, when the nominal balance would revert to the pre- modification balance. For example, borrowers may face recourse, in which case those with more principal forgiveness have more to lose in default.

To the right of the kink, default is increasing with pre- modification LTV, as expected, since higher pre- modification LTV implies higher post-modification LTV in this range (though the positive correlation between LTV and default is attenuated by the selection identified to the left of the kink). The true effect of principal forgiveness on default can be measured as the difference between the slopes to the left and right of the kink; the slope to the right of the kink reflects both selection and the effect of higher LTV, while the slope to the left of the kink reflects only selection. The slope to the right of the kink – a naive measure of the relationship between LTV and default – is therefore an underestimate of the true effect of LTV on default.

Table 2.5 exploits three kinks – sources of quasi-experimental variation – in the

program to provide four separate estimates of the impact of principal forgiveness on mortgage default. The first column repeats column 1 from Table 2.4. Column 2 (labeled “between”) relies on a between-servicer identification; it controls linearly for the borrower’s initial LTV, and interacts principal forgiveness from DTI (in 10 ppt bins) with the borrower’s initial LTV (also in 10 ppt bins). The coefficient on principal forgiveness is identified entirely from between-servicer differences in LTV targets servicer, comparing the experiences of borrowers with the same pre- modification LTV and DTI who received different amounts of principal forgiveness because their servicers had different LTV targets (115% or 100%). Column 3 limits the sample to borrowers whose servicer targets a 115% post-modification LTV, providing a “within” estimate (within the group whose servicers have a 115% LTV target). Column 4 limits the sample to borrowers whose servicer targets a 100% post-modification LTV, providing a “within” estimate (within the group whose servicers have a 100% LTV target). These servicers also cap principal forgiveness at 30 percent of the pre- modification unpaid balance. This column evaluates the impact of PR separately at each of the two kinks – the kink where the PR amount implied by DTI and LTV are equal and the kink where PR exceeds its cap. In order to identify the two kinks separately, we break the predicted PR amount into two pieces: the natural log of the amount predicted without the cap, and the difference in the natural logs of the capped and uncapped PR amounts. We find that the point estimates on the two kinks are similar (the difference between the estimates is statistically indistinguishable from zero), though the coefficient on the second kink is not statistically significantly different from zero due to its large standard error.

Section 2.6.3 presents evidence on cross-group differences in the default-reducing benefits of principal forgiveness. We find that the effects are robust across subsamples, and we find little evidence that the effects of principal forgiveness vary by modification duration, by cohort, or by calendar quarter. The appendix shows that there is mixed

evidence on whether the effects of principal forgiveness vary with LTV.

Table 2.5: Separate Estimates from DTI-LTV and 30% Principal Forgiveness Cap Kink

Dep. Var.	Quarterly Exit Rate			
Sample	Full Sample		LTV Target of Sample	
			115%	100%
Identification	Full	Between	Within	Within
$\ln(1+PF)$	-0.851*** (0.148)	-1.130*** (0.224)	-0.615*** (0.173)	
$\ln(\text{pred PF uncapped})$				-0.925** (0.438)
$\ln(\text{uncapped PF}) - \ln(\text{capped PF})$				-0.486 (0.504)
$\ln(1 + PF_{LTV})$	0.380*** (0.137)		0.182 (0.135)	0.688*** (0.235)
$\ln(1 + PF_{DTI})$	-1.072*** (0.091)	0.577 (0.659)	-1.184*** (0.122)	-0.777*** (0.113)
$\ln(\text{LTV initial})$		0.502 (0.670)		
LTV bin x PF_{DTI} bin	No	Yes	No	No
Observations	244,132	244,132	200,146	43,876
Loan count	45,513	45,513	38,513	7,000
R^2	0.0289	0.0332	0.0261	0.0209

The first column of Table 2.5 repeats the baseline regression from the first column of Table 2.4. The second column includes controls for the interaction of the borrower's LTV (in 10 ppt bins) and DTI (in 10 ppt bins); the coefficient reflects the difference in post-modification LTV arising from differences in the servicers' LTV target. The third column repeats column 1 for loans whose servicers target 115% LTV. The final column limits the sample to servicers who target 100% LTV, and decomposes $\ln(1+PF)$ into $\ln(1+PF \text{ uncapped})$ and $\ln(1+PF \text{ capped}) - \ln(1+PF \text{ uncapped})$. This final column provides two estimates for the impact of principal forgiveness on program exit for the 100% LTV target sample, one from the DTI-LTV kink (the coefficient from $\ln(1+PF \text{ uncapped})$) and one from the 30% cap kink (the coefficient from $\ln(\text{capped PF}) - \ln(\text{uncapped PF})$). Errors are clustered by MSA.

2.4.2 Placebo Evidence

Ganong and Jager (2014) have argued that results identified from kink designs may simply capture a nonlinear relationship in the data that happens to have an inflec-

tion point close to the kink. This concern seems unlikely to explain our results, since the location of the kink in this paper varies from borrower-to-borrower based on their pre- modification DTI and the LTV target of their servicer. This variation in the location of the kink allows us to control non-parametrically for any non-linear relationship between pre- modification LTV and default that may be present in the data. As additional robustness checks, we also perform two placebo tests to confirm that the results that we attribute to principal forgiveness are not spurious. Table 2.6 presents the results of these exercises.

In the first placebo test (shown in columns 2 and 3), we consider a “placebo treatment”. In particular, this is the amount of principal forgiveness the borrower would have received had they had a servicer with a different LTV target.²⁰ The first column shows our baseline regression, repeating the first column from Table 2.4. Column 2 adds the placebo treatment variable; column 3 adds the full set of controls (as in column 4 of Table 2.4) to the specification in column 3. We can see that a marginally statistically-significant positive coefficient on this variable becomes negative and statistically indistinguishable from zero when the full set of controls is added; the coefficient on the actual principal forgiveness is nearly unaffected by the addition of this placebo treatment.

In the second test (shown in columns 4 and 5 from Table 2.6), we show the results of regressions using the first of two “placebo samples”. The same regressions are performed on a sample of Fannie Mae and Freddie Mac loans with pre- modification LTVs higher than the loan servicer’s LTV target. Fannie Mae and Freddie Mac do not participate in the principal forgiveness program, and these loans are therefore categorically ineligible for principal forgiveness. We calculate the principal forgiveness these

²⁰For borrowers whose servicers have a 115% LTV target, this variable reflects the principal forgiveness amount they would have received had their servicer instead used a 100% LTV target and a 30% cap; for borrowers whose servicers have a 100% LTV target and a 30% cap, this variable reflects the principal forgiveness amount they would have received had their servicer instead used a 115% LTV target.

borrowers would have received had they been eligible for HAMP PRA. The results in columns 4 and 5 show that the amount of principal forgiveness that these borrowers would have received (but did not because they were ineligible) has no effect on their probability of default; the coefficient on $\ln(1+PF)$ is close to zero and statistically insignificant. These results are apparent in column 4 (which includes only the baseline regression, replicating column 1 from Table 2.4) and in column 5 (which adds the full set of controls).

In the third test (shown in columns 6 and 7 from Table 2.6), we show the second placebo sample. The baseline regression and a regression with the full set of controls are performed on a sample of investor-owned loans that were modified during the sample period but did not receive principal forgiveness. Because the HAMP PRA program allows investor restrictions to supersede HAMP rules, securitized non-GSE loans occasionally face investor restrictions that prohibit principal forgiveness. We cannot directly identify loans that face these restrictions; the loans in this sample have been denied principal forgiveness either because investor restrictions prohibit it, or because the NPV of a modification without principal forgiveness was calculated to be higher. In column 6 of Table 2.6, we make no attempt to distinguish between loans that were denied principal forgiveness for legal versus economic reasons. In column 7, we introduce the full set of controls, which include the variables that are most important for determining a borrower's NPV outcome. Without the controls, the coefficient of interest is statistically insignificant and reasonably close to zero. With the controls, the coefficient switches sign, the result is statistically indistinguishable from zero, and the standard error is large. Together, these results suggest no evidence of a change in behavior around the kink on the two samples of borrowers who do not receive the treatment and for whom we should not expect any differences in default rates around the kink.

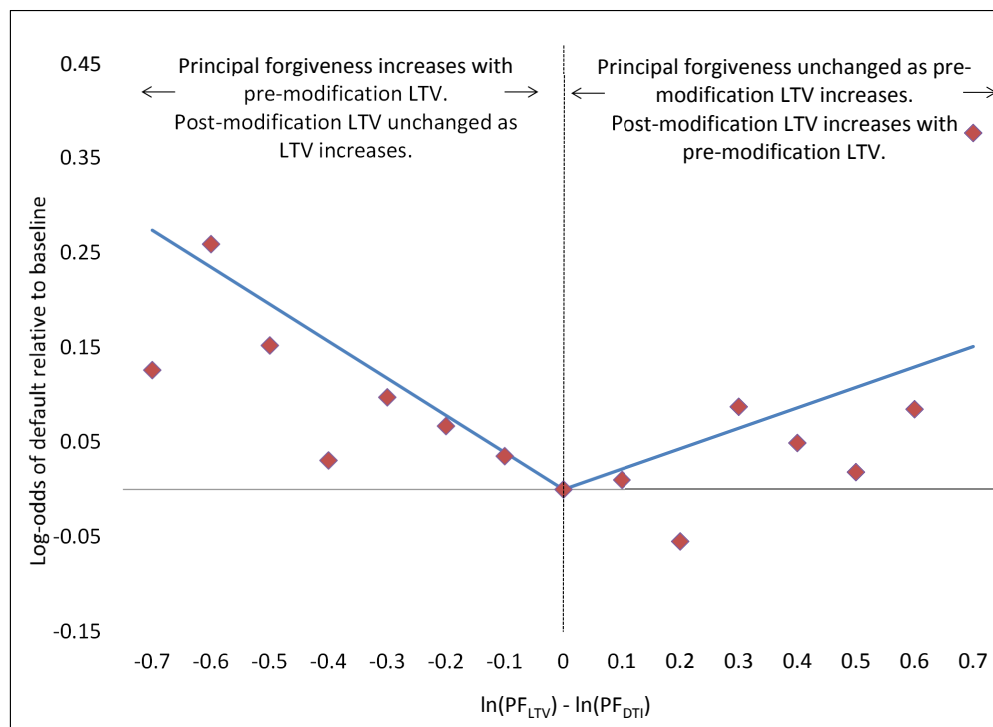


Figure 2.3: Graphical Evidence of Kink: Effect of pre- modification LTV (Relative to Kink) on Default Hazard

The x-axis represents the distance from the kink in logs, or $\ln(1 + PF_{LTV}) - \ln(1 + PF_{DTI})$. The y-axis is normalized to zero at the kink (x-axis of zero). The y-axis values of the diamond-shaped red dots indicate, for the baseline sample, the coefficients on the distance from the kink (in logs), in 10 percentage-point bins, in a logistic quarterly hazard regression to predict default. A y-axis value of 0.1 suggests a default odds of 0.1 log-points higher than at the kink (and therefore a default rate that is roughly 10 percent higher than at the kink), ceteris paribus. The blue line illustrates the coefficients on continuous variables measuring positive and negative distances from the kink (in logs).

Source: Authors' analysis of HAMP data.

Table 2.6: Quarterly Hazard: Placebo Tests

Dep. Var.	Quarterly Exit Rate					
	Full			Sample		
				Placebo (GSE)	Placebo (investor)	
$\ln(1 + PF)$	-0.851 *** (0.148)	-0.911 *** (0.150)	-0.994 *** (0.332)	0.084 (0.128)	-0.130 (0.143)	0.356 (0.318)
$\ln(1 + PF_{LTV})$	0.380 *** (0.137)	0.328 ** (0.140)	-0.617 (0.562)	0.343 *** (0.085)	0.592 *** (0.816)	0.928
$\ln(1 + PF_{DPI})$	-1.072 *** (0.091)	-1.114 *** (0.094)	2.375 *** (0.778)	-1.658 *** (0.044)	-1.164 *** (0.047)	1.974 ** (0.925)
$\ln(\text{placebo PF})$		0.282 ** (0.134)	-0.213 (0.289))			
Dummy for LTV target = 115	YES	YES	YES	YES	YES	YES
Quarters of observation controls?	YES	YES	YES	YES	YES	YES
Full set of controls?	NO	NO	YES	NO	NO	YES
Observations	244,132	244,132	159,826	293,962	277,394	161,556
Loan count	45,513	45,513	29,522	52,862	42,209	24,458
R^2	0.029	0.039	0.083	0.042	0.019	0.091

Column 1 reproduces column 1 from Table 2.4. Column 2 uses the same sample and adds a variable $\ln(\text{Placebo PF})$ which is the logarithm of the amount of principal forgiveness a borrower would receive if their servicer were following the alternative PF policy; for borrowers with servicers targeting 115% LTV, this value is the amount of PF necessary to achieve a 100% LTV target with a 30% cap, and vice versa. Column 3 adds the full set of controls. Column 4 replicates column 1 using only data for borrowers with GSE mortgages. Column 5 adds the full set of control variables. Column 6 replicates column 1 using only data for borrowers with loans serviced on behalf of third-party investors. Column 6 repeats column 7 and adds the full set of controls. Standard errors are clustered by MSA.

We replicate Figure 2.3 in Section 2.6.3, and contrast results from the placebo sample of GSE loans with PRA-recipients. In contrast with our sample of PF recipients, the relationship between default probability and pre- modification LTV (holding constant pre- modification DTI) shows no sign of change at the kink in the placebo sample.

2.4.3 Counterfactual Estimates

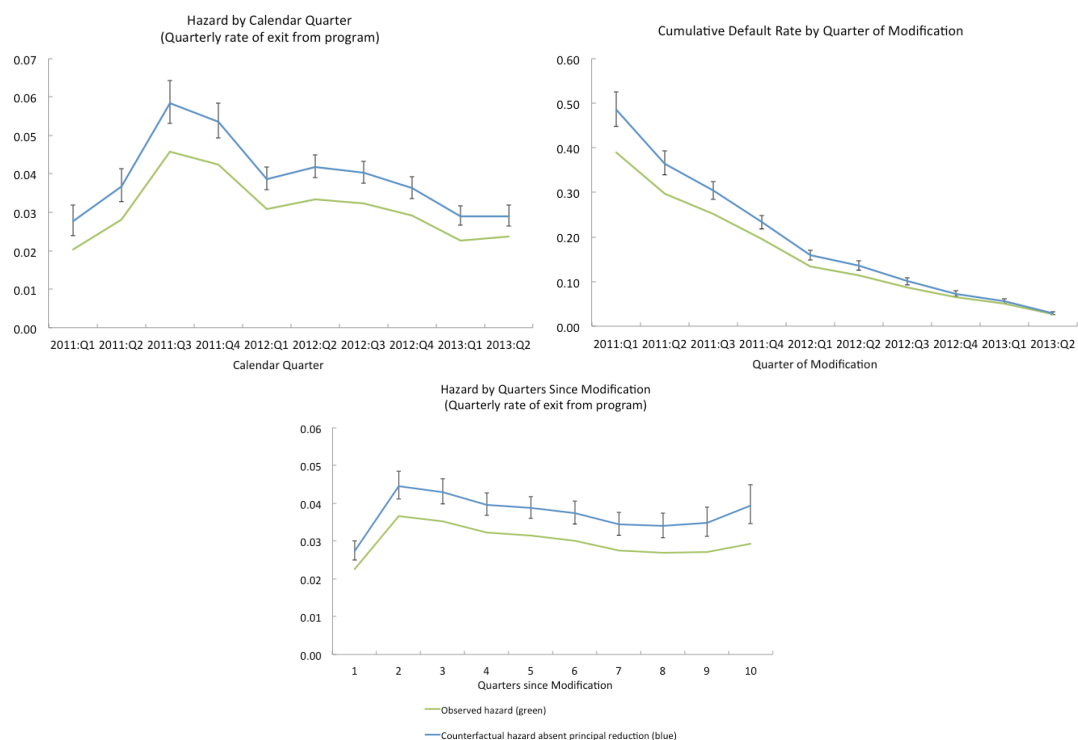


Figure 2.4: Counterfactual: Estimated default rates absent principal forgiveness

The counterfactuals are estimated using the regression shown in the first column of Table 2.4 with additional controls for the quarter of modification (linear), an interaction between $\ln(1+PF)$ and the number of quarters since modification, and an interaction between $\ln(1+PF)$ and the calendar quarter of modification. This regression is also the last column in Table 2.9. For each mortgage in our sample, we calculate the counterfactual likelihood of survival to date and the default hazard; these are calculated in each quarter in which that mortgage would have been in the sample had it not never defaulted. These are used to compute an average hazard weighted by the predicted probability of survival to date. The error bars encompass the predicted default rates within two standard deviations of the point estimate.

The results from the estimates in Table 2.4 can be used to construct a counterfactual in which borrowers receive no principal forgiveness, assuming the same payment

reduction had been achieved through rate reduction, term extension, and forbearance.²¹ Figure 2.4 illustrates the observed and counterfactual default rates for the sample population in several different ways. The first panel shows the cumulative default rate, by modification quarter, for loans that received principal forgiveness through HAMP PRA and the estimated cumulative default rate absent principal forgiveness. The second panel shows the quarterly exit rate in each calendar quarter. The final panel shows by loan duration – i.e., the number of quarters the loan has remained in the program. In each panel, the error bars encompass the predicted default rates within two standard deviations from the point estimate.

We estimate that the quarterly hazard rate would have been 3.8% (95% confidence interval (CI): 3.5% to 4.1%) – as compared to the 3.1% hazard observed in the data – had these borrowers not received principal forgiveness, which averaged 28.2% of the unpaid balance. The first cohorts of PRA modifications in our sample (those originated in the first half of 2011) had a cumulative default rate of 31% during the 9 to 10 quarters of observed performance. We estimate that their default rate would have been 37% absent principal forgiveness (95% CI: 34% to 40%). The cumulative default rate in the sample (overall default rate thus far) is 16.3%; we estimate that it would have been 19.6% (95% CI: 18.1% to 20.8%) had these loans not received principal forgiveness. These results do not change when we cluster errors by loan identifier, clustering all quarters of data from the same loan.

Our analysis sheds light on one of the major housing finance policy debates of the last several years: should FHFA should have recommended that the GSEs offer HAMP PRA-style modifications to struggling borrowers (Demarco, 2012)? To speak to

²¹The counterfactuals are estimated using the regression shown in the first column of Table 2.4 with additional controls for the quarter of modification (linear), and interactions between $\ln(1+PF)$ and the number of quarters since modification and the quarter of modification. For each mortgage in our sample, we calculate the counterfactual likelihood of survival to date and the default hazard; these are calculated in each quarter in which that mortgage would have been in the sample had it not defaulted.

this question, we use a logistic model to predict the quarterly default hazard for the sample of GSE (non-PRA) HAMP modifications with PRA-participating servicers and pre-modification LTVs above their servicer’s LTV target. These loans enrolled in the HAMP program during the same period as our main sample; they received a modification that mirrored the “standard” HAMP modification without principal forgiveness. We fit this model using the full set of covariates in column 4 of Table 2.4.²² The cumulative default rate for GSE loans from the first cohorts of this sample (those originated in the first half of 2011) was 32 percent over the 9 to 10 quarters following modification. Using the coefficients on the effect of principal forgiveness in this section, we estimate that the default rate would have been 28 percent had these loans received HAMP PRA.²³ Principal forgiveness would have averaged about 22 percent of the initial UPB in this sample, or about \$55,000; this implies that GSEs would have to write down approximately \$1.3 million to avoid one default over the 9 to 10 quarter window.

2.4.4 Proximity to the Kink

Table 2.7 repeats results from the first column of Table 2.4, with samples that sequentially (moving from left to right) zoom in closer around the identifying kink in equation (2.4). Limiting the regression to observations near the kink implements a regression kink design (RKD) (Florens et al., 2009; Card et al., 2012). Provided the region around the kink is small enough and assignment on either side of the kink is quasi-random, unobservables should be the same on either side of the kink. As a result, additional controls are unnecessary and concerns about omitted variables are lessened.

²²The regression differs from the one used on the HAMP PRA sample by replacing $\ln(1 + PF_{DTI})$ and $\ln(1 + PF_{LTV})$ with controls for pre- and post-modification DTI and pre-modification LTV (in logs).

²³This result assumes that the effect of principal forgiveness on GSE loans and privately-held loans is similar after controlling for observable differences. We were unable to limit the GSE sample to loans where principal forgiveness improves the NPV of the modification because the NPV test results are not available for GSE loans. As a result, our counterfactual estimate without an NPV screen understates the benefits of implementing HAMP PRA-style modifications with an NPV screen on the GSE sample.

The first column includes the full sample; the second excludes loans that are bound by the principal forgiveness cap (i.e., whose PF would be greater than 30% of their principal balance before modification, and whose servicers employ a cap). The third column includes uncapped loans within 0.5 log points of the kink, and the fourth column includes uncapped loans within 0.25 log points of the kink; standard errors become extremely large for tighter ranges. Note that results are roughly unchanged when the regression is limited to the neighborhood around the identifying kink; while standard errors grow as the neighborhood shrinks, point estimates change little.

It should not be surprising that we lose power in the region very near the kink. Borrowers who are near but on opposite sides of the kink receive nearly identical treatments. One must look relatively far from the kink to find borrowers with substantial differences in principal forgiveness, and consequently different default rates. It is worth noting that the kink occurs at different LTV values depending on the borrower's DTI and servicer PRA policy. As a result, identification from borrowers who are substantially far from the kink does not rely on borrowers with outlier DTI or LTV values or require any assumptions about the independent impact of LTV or DTI on default.

2.4.5 Earned Forgiveness Interpretation

In HAMP PRA, principal forgiveness is nominally granted in three equal installments after the borrower has been in the program for 12 months, 24 months, and 36 months, respectively. For borrowers who do not default on their loans, this “earned forgiveness” is irrelevant; borrowers receive the full amount of the principal forgiveness if they pay off their loan at any time. For borrowers who default within 36 months of receiving a HAMP PRA modification, the unearned portion of the principal forgiveness is converted to forbearance; the lender may demand repayment of this amount as part of a future foreclosure, short-sale, or other legal proceeding.

Table 2.7: Quarterly Hazard: Impact of Principal Forgiveness Near Kink

Sample	Dep. Var.: Quarterly Exit Rate			
	Full	Uncapped	Distance from Kink ≤ 0.5	Distance from Kink ≤ 0.25
$\ln(1+PF)$	-0.851*** (0.148)	-0.748*** (0.153)	-0.566*** (0.203)	-0.421 (0.466)
$\ln(1 + PF_{LTV})$	0.380*** (0.137)	0.308** (0.138)	0.112 (0.139)	-0.242 (0.287)
$\ln(1 + PF_{DTI})$	-0.539*** (0.032)	-0.479*** (0.037)	-0.451*** (0.043)	-0.448*** (0.056)
Observations	244,132	216,407	143,851	83,913
Loan count	45,513	41,339	27,641	16,200
R^2	0.029	0.0308	0.0213	0.0182

This table repeats results from the first column of Table 2.4, with the sample restricted to those observations sufficiently close to the kink from equation (2.4). The first column is identical to the first column from Table 2.4; the second column restricts the sample to observations not bound by the restriction that principal forgiveness not exceed 30% of the mortgage balance; the third column additionally restricts the sample to observations within 0.5 log points of the kink; the final column restricts the sample to observations within 0.25 log points of the kink. Standard errors are clustered by MSA.

One alternative to the hypothesis that lower mortgage balances (and the principal forgiveness that leads to them) reduce mortgage default *per se* is that borrowers who plan to default may want principal forgiveness in order to negotiate a better short sale or, in recourse states, relieve themselves of legal claims. In this case, borrowers may delay default until principal forgiveness is earned; it is not principal forgiveness – but, instead, the prospect of earning principal forgiveness in the future – that reduces default. If this were the case, one might see elevated default rates immediately following the months in which principal forgiveness is earned, namely at 12 months, 24 months, and 36 months after the modification date. In fact, there is no evidence of this; default rates do not spike at these dates in our sample (see Section 2.6.4. To probe this point further, we interacted dummies for the month the principal forgiveness is realized with the borrower’s predicted forgiveness amount, and we observed no statistically significant change in default probability.

2.4.6 Selection Bias and External Validity

Selection could be create two sources of bias for our estimates of the effect of principal reduction on the sample of loans that received HAMP PRA. First, within the sample of HAMP PRA loans, loans with higher unobservable default rates might receive more (or less) principal forgiveness. Second, loans with higher unobservable default rates that would receive more (or less) principal forgiveness under HAMP PRA might be more (or less) likely to select into the program.

Program rules and our identification strategy are designed to be robust to the first concern. Participating servicers were required to sign a Servicer Participation Agreement (SPA), which obligates them to comply with HAMP protocols on all of the loans in their servicing portfolio, to the extent permitted by their pre-existing contracts with mortgage investors. Servicers must offer the same principal forgiveness amount to all similarly-situated borrowers, and we observe and control for all covariates in this calculation (Making Home Affordable, 2014). For example, a servicer could elect to offer HAMP PRA to otherwise-eligible borrowers only when the NPV of the HAMP modification exceeded the NPV of a standard modification, or when the NPV of the PRA modification was greater than the NPV of no modification. The fact that HAMP PRA recipients receive almost exactly the amount of principal forgiveness predicted by program rules suggests that servicers and borrowers have limited scope to adjust principal forgiveness amounts. A regression to predict the natural log of actual principal forgiveness with the natural log of predicted principal forgiveness and no other covariates has a precisely-estimated coefficient of 0.99 and an R^2 of 0.99. An alternative version of this regression – predicting log post-modification LTV with dummy variables for binned distance from the kink and a control for log principal forgiveness needed to hit DTI target is displayed graphically in Section 2.6.5 Figure 2.8.

The absence of “bunching” also suggest that borrowers and servicers have lim-

ited scope to adjust principal forgiveness amounts. The identifying assumption of the kink design is that the unobservable propensity to default is smooth around the kink. Absent any reason to believe that being near the kink would affect default rates per se, there are scenarios in which this assumption might be violated. First, some people may try to manipulate their location relative to the kink. Second, individuals may selectively apply for (or prematurely drop out of) HAMP based on their location relative to the kink. These behaviors will show up as ‘bunching’, or counts of loans that are uneven around the kink (Card et al., 2012).²⁴ The histograms in Section 2.6.6 show no evidence of such bunching.

While the second concern – bias stemming from selection into HAMP PRA – poses more serious challenge, program rules also limit the scope of this problem. Since borrowers are offered only one modification, borrowers cannot choose which modification they receive. Servicers must offer HAMP PRA to all similarly-situated borrowers who meet program criteria, and we observe and control for all covariates (except for investor restrictions) that determine eligibility.²⁵

We can also look for direct evidence of bias stemming from selection into HAMP

²⁴For either of these concerns to arise, individuals would have to have precise information about where they would lie relative to the kink. This may be difficult since servicers’ LTV targets are not generally known to the public. Furthermore, servicers are required to use regulator-approved automated valuation models to determine the value of the home; borrowers generally do not know the algorithms used in these models.

²⁵However, we cannot perfectly predict receipt of HAMP PRA using the NPV test results submitted with the loans for several reasons. First, servicers expanded the program at different rates following the October 2010 program start date. Second, in February 2012, the federal government and 49 state attorneys general reached a settlement with five large servicers that required servicers to either grant principal forgiveness to borrowers or pay penalties. The implicit subsidy rate to principal forgiveness was somewhat higher than PRA subsidies for portfolio loans, and comparable to PRA subsidies for investor-owned loans. Borrowers receiving principal forgiveness for credit toward their settlement obligations were not considered PRA participants, because the principal forgiveness was structured somewhat differently, and was not subsidized by HAMP. Third, we cannot observe investor restrictions, which may prevent servicers from granting principal forgiveness on certain loans. A logit to predict principal forgiveness that includes a dummy for whether the loan is NPV positive for principal forgiveness relative to standard HAMP, a dummy for whether the loan is NPV positive for principal forgiveness relative to no modification, the logged difference between NPV results for PRA and standard modifications, modification quarter dummies interacted with servicer dummies, and the full set of control variables in column 4 of Table 2.4 yields an R^2 of 0.63 for portfolio-held loans and 0.52 for investor-owned loans.

PRA. To assess concerns that HAMP participants may select into HAMP PRA based on unobservables, we use a two-step Heckman-style estimator. (Heckman, 1979) In our first step, we estimate participation in HAMP PRA among HAMP participants. We use a logit specification with the covariates from the regression in column 4 of Table 2.4.²⁶ We add an additional covariate to the first step as an exclusion restriction under the assumption that this variable will affect participation in HAMP PRA but have no independent effect on the default hazard. This covariate is the proportion of HAMP modifications from the loan's servicer in the loan's modification quarter that received a HAMP PRA modification; even after controlling for servicer and quarter of modification, there is substantial variation in this variable stemming from differences across servicers in HAMP PRA roll-out timing. Unsurprisingly, this covariate has an extremely strong effect on the probability of receiving HAMP PRA. We include the residual from this first stage regression as a covariate in the second-step regression to predict the default hazard, again using the covariates from column 4 of Table 2.4. The coefficient on the first-step residual in the second step is insignificantly different from zero, and including it (along with an interaction with the principal forgiveness amount) has no material effect on the coefficient on principal forgiveness. This result suggests that differential selection into HAMP PRA by HAMP participants on unobservables does not contaminate or bias our estimates. Since we have no data on non-HAMP borrowers, we have no way to assess bias stemming from selection into the HAMP program more generally.

Even if our coefficients provide an unbiased estimate of the effect of principal forgiveness within the sample of loans that received HAMP PRA, these results may not generalize to other samples. We have no way to assess whether our estimates would be appropriate for other samples, such as the sample of GSE loans, loans that are not delinquent, HAMP loans that did not receive HAMP PRA (e.g., because standard HAMP

²⁶Since each loan appears only once in this first step, instead of once per quarter in the second step, we exclude loan tenure calendar controls from this regression.

yielded a higher NPV), or loans outside the HAMP program. Even if our coefficients are appropriate for these samples, the default-reducing benefits of principal forgiveness may be different for these groups if their baseline default rate was different. For example, we use a logistic model to predict the quarterly default hazard for the sample of loans that received a “standard HAMP” modification without principal forgiveness because this modification yielded a higher NPV than the HAMP PRA modification. These loans enrolled in the HAMP program during the same period as our main sample. We fit this model using the full set of covariates in column 4 of table 2.4.²⁷ The cumulative default rate for these NPV-negative loans from the first cohort of this sample (those originated in the first half of 2011) was 18.8% over the 9 to 10 quarters following modification. Using the coefficients on the effect of principal forgiveness in Section 2.4.3, we estimate that the default rate would have been 16.5% had these loans received HAMP PRA. Principal forgiveness would have averaged about 25% percent of the initial UPB in this sample, or about \$93,000; this implies that one would have to write down approximately \$4.3 million to avoid one default over the 9 to 10 quarter window. The much lower efficacy of principal forgiveness estimated for this sample stems solely from its lower baseline default hazard and different covariates.

2.5 Conclusion

Principal forgiveness has gained wide use in residential mortgage modifications only in the last several years, and many policymakers and academics have argued that it should have played a more central role in mitigating the broader economic effects of the recent housing crisis. Principal forgiveness certainly carries many benefits for mortgage borrowers, in that it transfers some of the decline in housing wealth to lenders

²⁷The regression differs from the one used on the HAMP PRA sample by replacing $\ln(1 + PF_{DTI})$ and $\ln(1 + PF_{LTV})$ with controls for pre- and post-modification DTI and pre- modification LTV (in logs).

and improves households' balance sheets. Our research suggests that for the liquidity-constrained borrowers likely to enroll in mortgage modification programs, increasing the wealth of borrowers by reducing their mortgage balances also modestly reduces default probability.

The quarterly hazard - the proportion of loans that become more than 90 days delinquent and consequently exit the program - is 3.1% in our sample; we estimate it would have been 3.8% absent principal forgiveness, which averaged 28% of the initial mortgage balance. The first cohorts of PRA modifications in our sample (those originated in the first half of 2011) had a cumulative default rate of 31%; we estimate that the default rate would have been 37% (95% CI: 34% to 40%) absent principal forgiveness. This 6 percentage point reduction in default rate implies that 17 mortgages must be written down to avoid a single foreclosure. Given the amount of principal forgiveness (averaging \$76,000 in the first cohorts), our point estimates imply that about \$1.3 million was written down per foreclosure avoided during the 9-10 quarter sample period available for the first cohort.

The government subsidy for principal forgiveness in HAMP PRA averaged about \$21,000 in the first cohorts, which – given the 6 percentage point reduction in the default probability – implies that the government spent \$362,000 in subsidies per avoided foreclosure during the 9 to 10 quarter sample period. This is certainly a substantial cost per foreclosure avoided. While there may be alternative policies that reduce defaults more cheaply, such policies will face two key challenges. First, even if they successfully reduce the probability of default to nearly zero, they may only reduce the probability of default by a few percentage points if default is unlikely without further intervention; as such, the number of avoided foreclosures will be far smaller than the number of treated mortgages. Second, the subsidy needed to induce lenders to further reduce principal balances will increase on loans that are less likely to default without further intervention.

For such a large write-down per avoided foreclosure to be cost effective for investors, one would have to believe some combination of three things. First, the vast majority of forgiven principal would never have been repaid absent principal forgiveness; the default rate absent principal forgiveness would have been very high.²⁸ Second, substantial default-reducing benefits of the program will come after the observed 10 quarter window.²⁹ Third, the costs of foreclosure are quite large.

The HAMP program was designed to increase the value of each mortgage for investors. The NPV test used to evaluate the value of each modification was rolled out with the HAMP program, before principal forgiveness was widely used in mortgage modifications. The HAMP NPV default model was forced to take a position on the effect of principal forgiveness on the lifetime default rate before evidence became available. Our analysis makes it possible to assess its performance. We apply the HAMP NPV test's default model to the first cohort of HAMP PRA loans to calculate their predicted default rate with and without principal forgiveness. The NPV default model predicts that this cohort of loans would have a lifetime default rate of 69% given the HAMP PRA modification they received, and an 80% lifetime default rate had they received an otherwise similar modification without principal forgiveness. This sample had a 31% default rate after 9 to 10 quarters, and we estimate this default rate would have been 37% had they received an otherwise similar modification without principal forgiveness.

²⁸The cost of providing principal forgiveness is lower when the lifetime default rate absent principal forgiveness is high. With only 10 quarters of post-modification data now available, that lifetime default rate is difficult to predict. The cumulative counterfactual default hazard among principal-recipients is nearly 40% after 9 to 10 quarters among borrowers whose HAMP PRA modifications became permanent in the first half of 2011, and the quarterly hazard has not dropped substantially over time. This suggests that the lifetime default rate might be quite high.

²⁹There is reason to believe that the default-reducing benefit to principal forgiveness may not remain constant over time. Following 5 years of participation in HAMP, borrowers who received rate reductions will begin to see their mortgage rates step up to the PMMS rate that prevailed at the time of modification. If a substantial share of borrowers remain underwater at that point, it is possible that principal forgiveness recipients will be better positioned to weather those payment shocks. On the other hand, we might expect the impact of principal forgiveness to decline as both recipients and non-recipients regain their equity positions.

While the time horizons of the two analyses make them difficult to compare directly, the default-reducing benefits of principal reduction are relatively similar in the HAMP NPV test and our analysis in a proportional sense.

Our results require several caveats. First, they may lack external validity or generalizability. The estimates in this paper are for a sample of mostly-delinquent borrowers with mortgages deemed unaffordable based on DTI criteria who undertook the substantial task of applying for a mortgage modification program. Principal forgiveness may have a different impact among lower-risk borrowers who were not delinquent or whose initial mortgage payments were affordable; or, given documentation required for the HAMP program, successful applicants may have a substantially different baseline default rate than the general delinquent population. Second, estimates are local in the range of the data; all HAMP PRA modifications bring monthly payments to a level deemed affordable, but not lower. We cannot directly test the ‘dual-trigger’ hypothesis (e.g., Foote et al. (2008)), which suggests that the impact of negative equity on default decreases with affordability. Third, our counterfactual estimates measure the impact of principal forgiveness on default only for borrowers who participate in the program. They do not measure the impact of principal forgiveness in HAMP on borrowers’ propensity to apply to the program – either because they would have proceeded to foreclosure absent the potential for principal forgiveness, or because they became delinquent in order to receive principal forgiveness. Fourth, HAMP PRA modifications are relatively new; as a result, re-default rates are available for at most 10 quarters from modification.

Chapter 2, in full, which is coauthored with Stephen H. Shore, has been submitted for publication as it may appear in *The Review of Financial Studies*, 2015. For their comments and insight on Chapter 2, Stephen Shore and I thank Alex Gelber, Gene Amromin, Jane Dokko, Paul Willen, Kris Gerardi, Chris Foote, Jeffrey Zabel, Peter Ganong, Simon Jäger, Matthew McCormick, Benjamin Kay, Sarada, and seminar participants at the University of California at Santa Barbara, Georgia State University, Temple University, the Boston Area Urban and Real Estate Economics Seminar, the Federal Reserve Bank of Atlanta, the Office of Financial Research at the U.S. Treasury Department, Florida International University, and the Consumer Finance Protection Bureau.

2.6 Appendix

2.6.1 Enrollment

Figure 2.5 shows monthly enrollment in Standard HAMP and HAMP PRA from the beginning of the program through our sample period, for non-GSE loans with LTV over 115 percent. Enrollment in HAMP PRA picked up through the beginning of 2012, but decreased as a share of HAMP modifications as the national servicer settlement displaced some HAMP PRA loans.

2.6.2 Placebo Evidence

Figure 2.6 replicates Figure 2.3 and adds the coefficients from the same regression on the first placebo sample (Fannie Mae and Freddie Mac loans). The difference between the behavior of the treated and placebo samples is remarkable. The placebo sample shows no change in behavior at the kink, and the default probability increases steadily in pre- modification LTV (which, for this sample, is the same as post-modification LTV).

2.6.3 Heterogeneity

Table 2.8 shows that the estimation results are robust to choice of sample, including ARM-only, FRM-only, private-investor-held, and portfolio-held. Table 2.9 allows the impact of principal forgiveness to vary with observables. Our estimates in Table 2.8 suggest that the impact of principal forgiveness may be greater for higher-LTV loans, though the significance of this finding is not robust. Table 2.9 uses a different specification and finds no significant difference in the effect of principal forgiveness on high- and low-LTV loans. The difference in statistical significance between these two specifi-

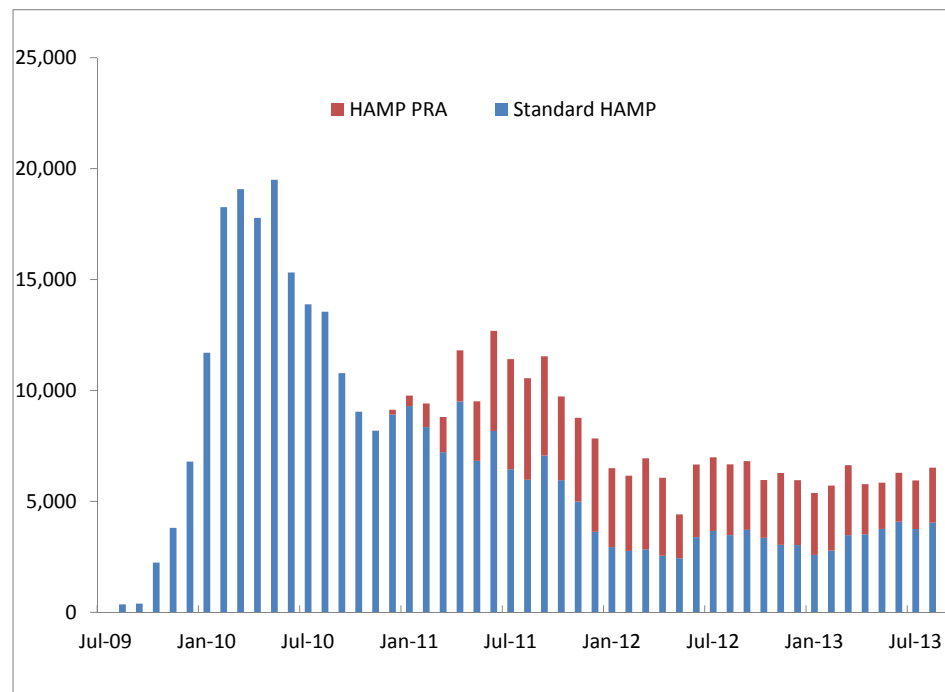


Figure 2.5: Enrollment in Standard HAMP and HAMP PRA for non-GSE loans with LTV over 115 Percent

Count of new permanent modifications for non-GSE loans with pre- modification LTV over 115 percent. The data span the first enrolled cohort (June 2009) through the end of our sample period (September 2013).

cations reflects differences in the effects of the control variables rather than differences in the functional form of the interaction between the LTV control and principal forgiveness. The second specification allows control variables to separately estimated for the high- and low-LTV populations, whereas the first specification estimates a single value for each control variable. Table 2.9 does not indicate a clear pattern in the impact of principal forgiveness by pre- modification mortgage affordability (TDTI, column 4). The impact of principal forgiveness does not appear increase or decrease monotonically

with modification age, and there does not appear to be a significant time trend to the performance of successive cohorts.

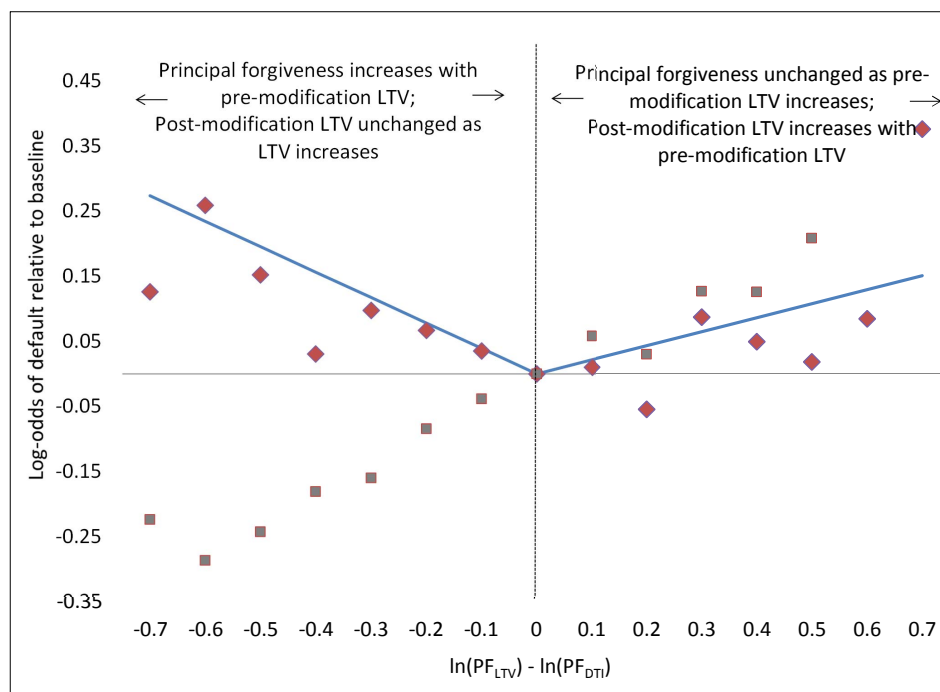


Figure 2.6: Graphical Evidence of Kink, with Placebo Sample
Effect of pre- modification LTV (Relative to Kink) on Default Hazard

The x-axis represents the distance from the kink in logs, or $\ln(1 + PF_{LTV}) - \ln(1 + PF_{DTI})$. The y-axis is normalized to zero at the kink (x-axis of zero). The y-axis values of the diamond-shaped red dots indicate, for the baseline sample, the coefficients on the distance from the kink (in logs), in 10 percentage-point bins, in a logistic quarterly hazard regression to predict default. A y-axis value of 0.1 suggests a default rate that is 10 percent higher than at the kink, ceteris paribus. The grey squares indicate those same coefficients for the placebo sample. The blue line illustrates the coefficients on continuous variables measuring positive and negative distances from the kink (in logs).

Table 2.8: Quarterly Hazard in Sub-Samples

Dep. Var.	Quarterly Exit Rate					
	Full	ARM	FRM	PLS	Portfolio	LTV $\leq$ 180
Sample						LTV $\geq$ 180
$\ln(1+PF)$	-0.851*** (0.129)	-0.945*** (0.210)	-0.771*** (0.167)	-0.796*** (0.165)	-0.728*** (0.218)	-1.371*** (0.215)
$\ln(1 + PF_{LTV})$	0.380*** (0.089)	0.504*** (0.145)	0.352*** (0.115)	0.518*** (0.108)	0.144 (0.161)	0.597*** (0.273)
$\ln(1 + PF_{DPI})$	-1.072*** (0.045)	-0.842*** (0.071)	-1.146*** (0.063)	-1.053*** (0.056)	-1.099*** (0.079)	-0.788*** (0.093)
LTV target equal to 115?	YES	YES	YES	YES	YES	YES
Quarters since modification	YES	YES	YES	YES	YES	YES
Observations	244,132	105,265	138,867	146,271	97,861	78,230
Loan count	45,513	18,867	26,646	29,412	16,101	14,460
R^2	0.0289	0.0225	0.0322	0.0336	0.0247	0.0354

This table repeats the results from the first column of Table 2.4, with columns differing in the sub-sample used for the regression. Results are shown for adjustable rate mortgages only (ARMs, column 2), fixed rate mortgages only (FRMs, column 3), private label securities (PLS, mortgages that have been securitized and not held on bank balance sheets, column 4), portfolio loans (mortgages that have been held on bank balance sheets, column 5), loans with a pre- modification LTV < 180 (column 6) and loans with a pre- modification LTV > 180 (column 7).

Source: Authors' analysis of HAMP data.

Table 2.9: Variation in Impact of Principal Forgiveness

Dep. Var.	Quarterly Exit Rate					
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(1+PF)$	-0.851*** (0.129)	-0.62** (0.264)	-0.228 (0.325)	-0.817*** (0.187)	-0.924*** (0.203)	-0.950*** (0.284)
$\ln(1+PF)$ x $\ln(\text{initial LTV})$		-0.409 (0.405)				
$\ln(1+PF)$ x $\ln(\text{initial TDTI})$			0.487 (0.349)			
$\ln(1+PF)$ x quarters since mod quarter of mod				-0.010 (0.039)	-0.095*** (0.014)	0.006 (0.041)
$\ln(1+PF)$ x quarter of mod				0.039 (0.045)	0.041 (0.047)	
Observations	244,132	244,132	244,132	244,132	244,132	244,132
Loan count	45,513	45,513	45,513	45,513	45,513	45,513
R^2	0.0289	0.0289	0.0385	0.0289	0.031	0.031

This table repeats the results from the first column of Table 2.4, allowing additional interaction effects.

2.6.4 Earned Forgiveness Interpretation

Figure 2.7 shows the monthly default hazard for PRA recipients modified during our sample period, by months since modification. We see no evidence of elevated default rates immediately following the months in which principal forgiveness is earned, namely at 12 months, 24 months, and 36 months after the modification date.

2.6.5 Kink in Treatment

Figure 2.8 illustrates the change in treatment at the kink, with the y-axis measuring the difference between the log post-modification LTV actually received and the LTV target, or $\ln(\text{actual post-modification LTV}) - \ln(\text{target LTV})$. The x-axis shows the log distance from the kink from equation 2.4, or $\ln(1 + \text{PF}_{\text{LTV}}) - \ln(1 + \text{PF}_{\text{DTI}})$. Perfect compliance with the program would be shown by a horizontal line at zero to the left of the kink, and a line with a slope of 1 to the right of the kink. More formally, the figure shows estimates of coefficients for 10 percentage-point bins for log distance from the kink (bin at the kink is the omitted category) from the following regression:

$$\begin{aligned} \ln(\text{actual post-modification LTV}) = & \alpha + \beta_{\text{DTI}}(\ln(1 + \text{PF}_{\text{DTI}})) \\ & + \beta_{\text{kink}}(\ln(1 + \text{PF}_{\text{LTV}}) - \ln(1 + \text{PF}_{\text{DTI}})) \\ & + \beta_X X + \varepsilon \end{aligned}$$

Additional controls include fixed effects for servicer, cohort, and the number of quarters since modification. The figure shows that actual post-modification LTV aligns almost exactly with the post-modification LTV predicted by HAMP PRA program rules.

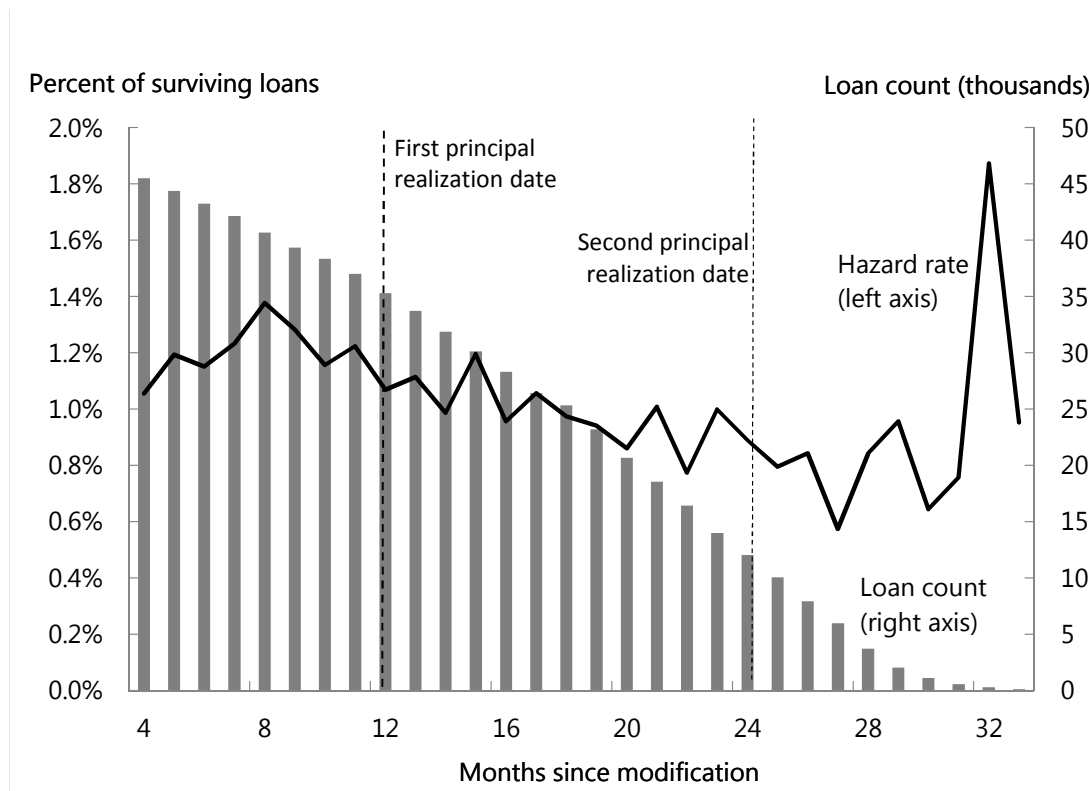


Figure 2.7: Monthly Default Hazard

2.6.6 Evidence of Bunching

The left panel of Figure 2.9 plots a histogram of the loans whose servicers use a 115% LTV target, and therefore have only one kink, by distance from the kink, or $\ln(1 + PF_{LTV}) - \ln(1 + PF_{DTI})$. The right panel plots a histogram of the distance from the second kink, measured as $\ln(1 + PF_{uncapped}) - \ln(1 + PF_{capped})$, for loans whose servicers use a 100% LTV target. These histograms show no evidence of “bunching” around the kinks.

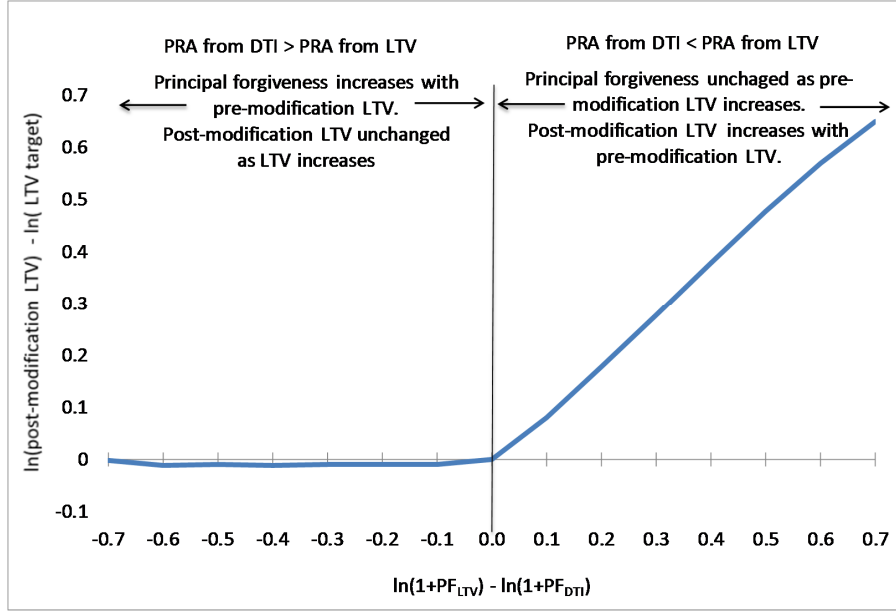


Figure 2.8: Treatment at Kink

The horizontal axis represents the distance from the kink, measured as $\ln(1 + PF_{LTV}) - \ln(1 + PF_{DTI})$. The plotted line reflects the coefficients from a regression of $\ln(\text{post-modification LTV})$ on the distance from the kink (in 10 log-point bins), controlling for $\ln(1 + PF_{DTI})$. The omitted category includes the point where the distance from the kink equals zero. To the left of the kink, the slope of the line implied by the coefficients is 0, because in this range, the LTV target is met. To the right of the kink, the slope implied by the coefficients is 1, the DTI constraint binds in this range, and the post-modification LTV remains above the LTV target.

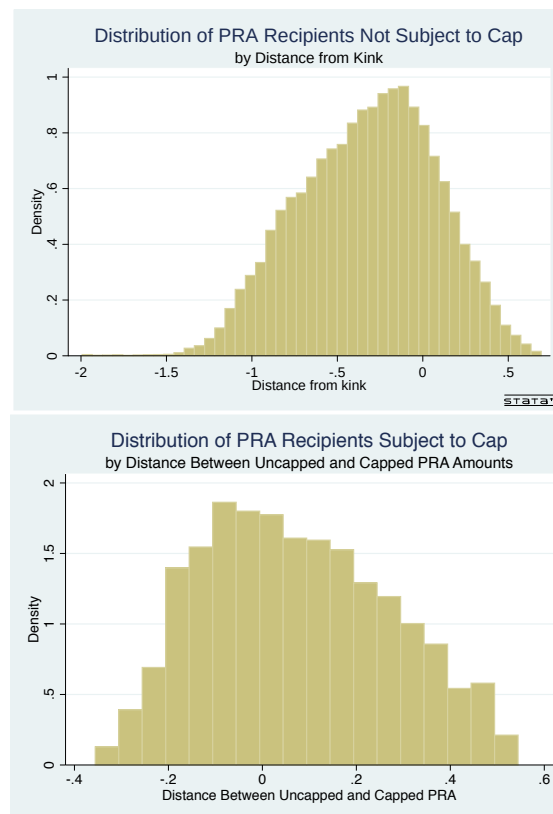


Figure 2.9: Evidence on Bunching Around the Kink

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Chapter 3

The HAMP NPV Model: Development and Early Performance

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REAL ESTATE ECONOMICS



The HAMP NPV Model: Development and Early Performance

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The foreclosure crisis that began in 2008 triggered the need for new approaches to treat distressed mortgages. A key component of the Obama Administration's Home Affordable Modification Program (HAMP) was the development of a standardized Net Present Value (NPV) Model to identify troubled loans that were value-enhancing candidates for payment-reducing modifications. This article discusses the development of the HAMP NPV Model,¹ its purpose and some important constraints that dictated its structure and limitations. We describe the structure and the estimation of the model in detail. We also describe the responsiveness of the model to key characteristics, such as loan-to-value and credit score, as well as provide new evidence on the relationship between HAMP modification performance and key borrower and modification characteristics. The article concludes with a discussion of model limitations and the future role of systematic loan modification using NPV analysis.

The first decade of the 21st century was as tumultuous for the housing sector as any in recent history. A sharp increase in housing-market activity, marked by a dramatic acceleration in home prices and new mortgage originations, was followed by a bust, during which delinquencies soared and housing prices

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¹The Home Affordable Modification Program (HAMP) is arguably the federal government's most important intervention into housing markets to encourage loan modifications for distressed homeowners. The creation and rollout of the Net Present Value (NPV) Model was a critical innovation in HAMP and has played an important role in the program. James Berkovec played an important role in developing the first version of the NPV, directing the development of the default model and offering substantial leadership and guidance throughout the process.

plummeted. The housing bust was marked by a nearly unprecedented increase in mortgage delinquencies and foreclosures; in the first quarter of 2010 the Mortgage Bankers Association's National Delinquency Survey experienced the highest ever rates of delinquency in the series' history. The spike in defaults and decline in home values resulting in the collapse of nonprime mortgage-backed securities (MBS) values was one of the chief proximate causes of the financial crisis.

The federal government took a number of extraordinary actions to address the crisis, including a series of efforts aimed at foreclosure avoidance. The largest of these efforts was the Home Affordable Modification Program (HAMP), launched in early 2009 using funding from the Troubled Asset Relief Program (TARP). As of the first quarter of 2011, HAMP had initiated over 1.5 million trial modifications and made permanent over 670,000 modifications. Over one hundred servicers accounting for about 80% of outstanding residential mortgage debt being serviced signed up to participate in HAMP.

HAMP was designed to facilitate bulk processing of loan modifications by requiring and subsidizing a specific streamlined modification structure, which could be evaluated by a single, batch-process, decision-making framework. Most pooling and servicing agreements require servicers to increase the value of cash flows to investors. In the context of modifications this can be interpreted as a requirement for present value improving modifications. HAMP was therefore designed to provide both a decision-making framework to neutrally assess the value of a specific modification structure and subsidies for mortgage investors to increase the value of modified loans.

HAMP emphasized bulk processing and a streamlined modification structure because at the beginning of the foreclosure crisis large mortgage servicers were unprepared for the overwhelming volumes of seriously delinquent loans and had minimal infrastructure for evaluating these loans for loss mitigation. The design of HAMP also reflects the understanding that in many cases loan modifications that would be value-improving for investors relative to foreclosure were not being identified and executed as a result of obstacles within the existing market structure.² In HAMP, value-enhancing modifications are identified using the Net Present Value (NPV) Model. The NPV Model compares the expected discounted cash flows associated with the modification of a loan—considering probabilities of default—under two scenarios: the loan is

²See Cordell, Dynan, Lehnert, Liang and Mausekopf (2009) for a discussion of institutional barriers to loan modification and Foote, Gerardi, Goette and Willen (2010) and Adelino, Gerardi and Willen (2009) discuss economic barriers to loan modification.

modified according to HAMP terms and the loan is not modified (hereafter referred to as “mod” and “no-mod”). A loan that is NPV “positive”—where the value of the probability-weighted mod cash flows exceed the value of the probability-weighted no-mod cash flows—is considered to be a good candidate for modification. Testing modifications for positive NPV generally eliminates borrowers who are very unlikely to be foreclosed upon or who have substantial positive equity, because in both cases the mortgagee or lien-holder is unlikely to suffer meaningful losses in the no-mod case. The NPV test also eliminates borrowers for whom a modification does not meaningfully reduce their prospects of foreclosure. In these cases the costs of the modification in terms of reduced cash flows are not balanced by a reduced probability of foreclosure.

This article reviews the development, mechanics and operation of the HAMP NPV Model, introduces initial measures of the performance of the model and offers a view of future challenges to the evaluation of modifications.³ The article is organized as follows: the first section discusses the HAMP program design, the second section describes the development of the NPV Model, the third section discusses the workings of the NPV Model, the fourth section provides simulation and empirical results that provide insight into the model outcomes, and the fifth section discusses limitations of the model, describes future challenges and opportunities and concludes.

HAMP Program Design

HAMP facilitates rapid, objective evaluation of loan modifications by providing a batch decision-making tool (the NPV Model) and a standardized modification structure. The program provides subsidies for servicers to conduct modifications, potentially ameliorating a recognized misalignment in financial incentives in servicing contracts (see Cordell *et al.* 2009). The program also increases the value of modifications to investors with the addition of subsidies to mortgage investors.

The program includes outreach and solicitation requirements to ensure fair and consistent treatment of all borrowers and helps to establish industry best practices in an area where few rules existed. Participating servicers must solicit all borrowers who become 60 or more days delinquent for a HAMP modification,

³The authors represent the working group tasked with development and enhancement of the NPV evaluation tool. The tool was designed to implement the administration’s HAMP policy. A discussion of the policy choices that influenced the design of the NPV Model is beyond the scope of this article.

and they are required to evaluate every eligible loan using the standardized modification terms and the standardized net present value test.⁴ The servicer is required to offer the homeowner a modification in cases where the proposed modification is NPV positive.⁵

The HAMP Modification

The HAMP modification is structured to achieve a first-lien mortgage-debt-service to income (hereafter “front-end DTI”) target of 31%. For an otherwise eligible modification to qualify for HAMP subsidies, the borrower’s monthly payments of principal and interest on their first lien, as well as taxes, insurance and homeowner association (HOA) fees must not exceed 31% of their gross monthly income.

The standard HAMP modification achieves the 31% DTI target through an unvarying sequence of three steps (hereafter referred to as the modification “waterfall”). The waterfall consists of: (1) a rate reduction to as low as 2%; (2) if necessary, a term extension up to 40 years and (3) as necessary, principal forbearance. The rate reduction remains in place for the first five years of the program. Following the fifth year, the borrower’s interest rate rises by one percentage point each year until it reaches the Freddie Mac Primary Mortgage Market Survey (PMMS) rate for 30-year fixed-rate mortgages that was in effect at the time the modification was underwritten.⁶ Principal forbearance remains in place for the duration of the loan, taking the form of a zero-coupon balloon payment due at maturity or when the mortgage is paid off.

HAMP Incentives

HAMP directly subsidizes all parties involved in the modification.⁷ The owner of the modified mortgage receives one-half the amount necessary to bring the mortgage payment from 38% DTI (or the current DTI, if lower) to the target

⁴In addition, the HAMP program can modify borrowers who servicers determine to be at risk of imminent risk of default even if they are current or only 30-day delinquent on their mortgage.

⁵Fannie Mae and Freddie Mac require modification if the NPV exceeds negative \$5,000.

⁶Information on the Freddie Mac Primary Mortgage Market Survey (PMMS) rate can be found at www.freddiemac.com/pmms/.

⁷For non-GSE mortgages, subsidies are financed by Treasury using Troubled Asset Relief Program (TARP) funds. The GSEs do not receive investor subsidies from TARP, and pay performance subsidies to borrowers from their own resources. However, when GSEs apply the NPV test, they calculate the NPV using the standard model, in effect acting as if they received TARP subsidies for performing the modifications.

DTI of 31% for the first five years of the program. Furthermore, the lien-holder will receive a \$1,500 payment for modifying current borrowers who are at imminent risk of default⁸ and may receive a home price decline protection payment.⁹ Servicers receive \$1,000 when a loan modification completes its trial plan, fulfills its documentation requirements, and becomes permanent; if the modification continues to perform, the servicer is eligible for an additional \$1,000 on each of the first three anniversaries of the modification, as well as additional incentives for modifying imminent default borrowers. Homeowners are eligible for up to five one-time payments toward principal reduction equal to \$1,000 each year if they make their payments on time.

Practical Considerations in NPV Model Development

Policymakers understood that a framework for systematic, consistent evaluation of the cash flows associated with modifications was crucial for facilitating a broad modification program. An NPV tool ensures a basic degree of consistency across servicers, provides protection for investors and mitigates some moral hazard concerns. As HAMP was designed, an inter-agency team was created to build the NPV tool. This team—comprised of staff from the Department of Treasury, Federal Housing Finance Agency, Housing and Urban Development, the Federal Reserve Board, the Federal Deposit Insurance Corporation, Fannie Mae and Freddie Mac—was charged with quickly developing and implementing a model. The development team faced several challenges and constraints in designing the model, which shaped the final product in important ways.

Rapid Processing and Integration with Servicer Operations

The NPV team was tasked with being both as accurate as possible for the widest variety of mortgages and servicers and sufficiently simple so that the model could be integrated into servicer protocols. It was critical that the model use only information that was being collected and documented to verify borrower eligibility and monthly payments or was otherwise readily available to servicers. These constraints limited the ability to capture some elements that would ideally be included in a comprehensive view of default and prepayment probabilities.

The default and prepayment probability models reflect these input constraints. Both models use inputs from a short list of sources: first-lien balance and delinquency information readily available from servicers' databases, income

⁸Borrower must successfully complete trial payments.

⁹Details of the home price protection payment are discussed in the Conceptual Framework of the NPV Model section.

information collected from the borrower for the purpose of identifying the appropriate payment level, the first-lien loan-to-value (LTV) ratio and the borrower's and co-borrower's FICO scores.¹⁰ A more complete view of the loan's history and viability—including information on second liens, other financial obligations and original underwriting documentation—is not consistently available for all borrowers. Credit information can often, but not always, yield some insight into other liens and financial obligations, but auditable algorithms would be required to standardize treatment of ambiguous lien information or optional monthly payments (*e.g.*, payments on credit card debts). Ultimately, the NPV team and HAMP program designers determined that the process changes were operationally burdensome in the context of the program and that these additional information requirements introduced documentation and validation risks that would differentially impact borrowers based on the composition of their mortgage and nonmortgage debt.

Limited Relevant Historical Data

The NPV development team had little direct information or experience from which to parameterize the components of the NPV Model. Historical mortgage industry data is of limited use in calibrating default and prepayment behavior generated by HAMP modifications, both because the HAMP modification is structurally different from modifications that preceded the program and because loan-level datasets are not sufficiently seasoned to capture historical periods with high default rates or widespread negative equity for the types of mortgages that were predominant among seriously delinquent loans. There was scant experience with modifications that resulted in substantial payment reductions. Prior to HAMP, most large servicers and the GSEs relied on capitalization of arrearages and short-term forbearance, neither of which resulted in meaningful payment reductions, as their primary approach for dealing with seriously delinquent loans (Office of the Comptroller of the Currency 2009). These loss-mitigation strategies were adequate to deal with delinquency stemming from brief periods of income interruption, but generally servicers did not have adequate tools for handling long-term affordability problems or serious negative equity.¹¹

¹⁰The first-lien LTV, updated for any changes to the principal balance of the mortgage or estimated value of the house, will be referred to as mark-to-market LTV (MTMLTV) to distinguish it from origination LTV.

¹¹See Capone (1996) for a history of loan workouts from the 1940s to the 1990s and Ghent (2011) for an analysis of loan workouts in the 1930s. Cutts and Green (2005) document the reduction of default rates through traditional modification. Comeau and Cordell (1998) describe Freddie Mac's development of automated loan modification

The NPV team used performance data from a variety of sources to set key parameters such as default responsiveness to MTMLTV, FICO and pre- and postmodification DTI. The most difficult and critical task was to determine the change in default probabilities generated by changes in DTI. This was an analytically challenging problem in part because loan-level datasets do not include updated income information and because of measurement issues with this variable.

Conceptual Framework of the Net Present Value Model

The role of the HAMP NPV Model is to assess whether or not a loan modification (and associated subsidy payments) will be beneficial from the investor's perspective.¹² A modification is "NPV positive" when the total discounted value of expected cash flows for the modified loan is higher than those for the unmodified loan. This section lays out the framework and key concepts of the NPV Model currently in use (NPV Version 4.0). A full discussion of the parameterization of the model and the data used for model calibration is available on the program's administrative website.¹³

The HAMP NPV Model uses a simple framework to evaluate four static paths: the modified loan cures, the modified loan redefaults, the unmodified loan cures and the unmodified loan proceeds through the foreclosure process. For ease of communication these paths will be referred to as "Mod Cure," "Mod Default," "No Mod Cure" and "No Mod Default." The probabilities associated with each path are determined by the default (p_{def}) and redefault (p_{redef}) models where the remaining percentage is associated with the probability of cure ($1 - p_{def}$, $1 - p_{redef}$). The present values of cash flows in each of the two paths associated with the modified loan (mod cure, mod default) are weighted by the path probabilities to obtain a present value of the modified loan. The present values of the two paths associated with the nonmodified loan are similarly weighed. The Net Present Value is the difference between the probability weighted cash flows in the mod and no-mod scenarios. Figure 1 illustrates this simple framework.

tools. Swagel (2009) describes post-financial crisis, pre-HAMP mortgage foreclosure avoidance policy development from a U.S. Treasury perspective. Mayer, Morrison, Piskorski and Gupta (2011) examine if offering mortgage modifications to seriously delinquent borrowers induces elevated rates of delinquency. Harding, Rosenblatt and Yao (2009) document the impact of foreclosures on the value of surrounding properties.

¹²For an academic study of the trade-offs in modification see Ambrose and Capone (1996)

¹³See <http://www.hmpadmin.com> in the "servicer documents" section of the website.

Figure 1 ■ Structure of NPV model.

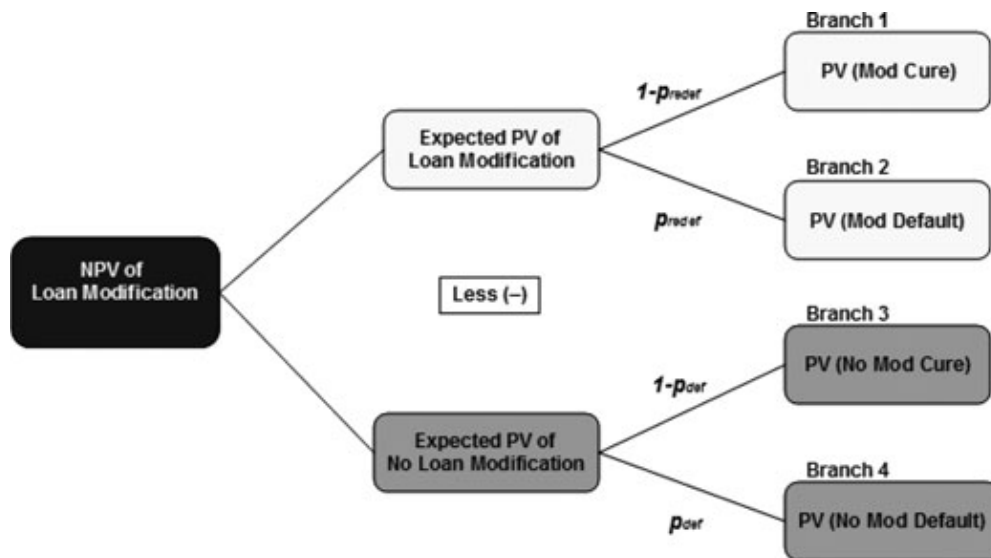


Figure 1 depicts the components and structure of the NPV calculation. Branch 1 represents the present value of cash flows if the modification does not redefault. Branch 2 represents the present value of cash flows if the modification does redefault. The probability weighted sum of these present values is equal to the expected present value of modifying the loan. Similarly, branches 3 and 4 are used to calculate the expected present value of nonmodification. The difference between the two expected present values is equal to the net present value of loan modification.

The next section evaluates each of the separate components of the model: the discount rate, the default model, the prepayment model, cure cash flows (branches 1 and 3 of Figure 1) and default cash flows (branches 2 and 4).

The Discount Rate

Discounting is performed at a rate appropriate for mortgage cash flows. The baseline discount rate is the Freddie Mac PMMS weekly rate for 30-year fixed-rate conforming loans. Servicers can override the baseline discount rate for private-label loans or loans in their portfolio by adding a risk premium of no more than 250 basis points to the PMMS weekly rate.

The Default Model

The default model is based on a logistic regression framework, and it is therefore nonlinear in its inputs. The variables determining default probability are the MTMLTV of the first-lien mortgage, the borrower's current credit score, the

borrower's DTI before the modification and the delinquency status of the loan.¹⁴ An additional term reflects the payment relief generated by the reduction in DTI: in the "No Mod" case it is set to zero and in the "Mod" case it is the percentage change in DTI granted by the modification.

For the standard HAMP modification, which changes the borrower's monthly payment but does not change the principal balance, the difference between the default probabilities in the mod and no-mod scenarios is generated entirely by the change in the borrower's DTI. Where principal write down is used, the modification reduces both the MTMLTV of the loan and the borrower's DTI. In this case, the reduction in the default probability reflects both a lowered LTV ratio and a reduced mortgage payment.

Consistent with intuition, predicted default rates increase with MTMLTV and starting DTI, and decrease with FICO scores. The model specifies a linear spline in the MTMLTV levels which allows kinks in the slope of the MTMLTV curve at the knot points located at 100 and 120 LTV.¹⁵ The benefit of the spline is that it allows a better representation of the default behavior for high LTV loans.

Predicted redefault rates are generally decreasing with starting DTI but can increase at very high DTI levels. An increase in starting DTI increases the borrower's risk of default, but the borrower also receives a greater reduction in monthly payments, which reduces the chance of redefault. Over low DTI ranges, the stabilizing feature of the payment reduction outweighs the influence of the starting DTI, and redefault probability declines in DTI. At very high starting DTI levels, the redefault probability suggested by the high initial DTI outweighs the stabilizing influence of the payment reduction, and overall redefault probability increases.

The model coefficients are calibrated to observed default rates for a broad loan population using data selected from HAMP modifications, Fannie Mae and Freddie Mac seasoned loans, ABS/MBS data from First American CoreLogic as well as other data. It is not a purely empirical specification as there are very limited data on modifications with HAMP-like contract terms. As the mortgage market gains experience with relevant modifications, the model will be increasingly empirically grounded.

¹⁴DTI refers to the front-end ratio. Front-end DTI is the ratio of principal, interest, taxes, insurance (including homeowners' insurance and hazard and flood insurance) and homeowners' association and/or condominium fees (PITIA) to gross monthly income. Private mortgage insurance is excluded from the PITIA calculation.

¹⁵Operationally, a linear spline with knot point, k , adds a variable into the regression of the form: $\max[0, \text{MTMLTV} - k]$.

The Prepayment Model

In contrast to the default model, which allocates default probabilities to a single point in time, the prepayment model calculates a prepayment probability for each month of the loan's scheduled amortization period. The model is estimated using a logistic regression model on a sample of GSE delinquent loans. The model is identical for loans in the mod and no-mod scenarios, though the inputs reflect the characteristics of the loan along each path. The key inputs of the model include delinquency level, refinancing incentive (effective spread to the PMMS rate), MTMLTV, previous 12-months' house price growth rate, current FICO and the original loan amount. Separate models are estimated for each loan delinquency status.

Cash Flows in Default

The model utilizes a simplified approach to the timing of default. In the non-modification scenario (branch 4), the model assumes that if the loan defaults, it defaults immediately and makes no further payments (Figure 1, branches 2 and 4). In the modification scenario (branch 2), the model assumes that the loan defaults six months after beginning the modified loan payments. The immediate default in the no-mod scenario reflects the fact that loans entering the program are generally either already quite delinquent or deemed by the servicer to be severely distressed and in imminent default. The six-month timeline for redefault in the mod scenario reflects the observed median time to redefault, conditional on eventually defaulting.

Once the loan defaults, it is assumed to proceed to foreclosure according to state-level foreclosure timelines, adjusting for the number of months the loan is delinquent at the time of evaluation for HAMP.¹⁶

In default the cash flow consists of proceeds minus costs: the REO net property disposition value minus taxes, insurance, and homeowners' association fees. All disposition-related cash flows are assumed to occur on the date of REO sale. These include state-varying foreclosure costs and REO disposition costs, mortgage insurance proceeds and state-varying net REO sales proceeds (estimated using the current property value and a state-varying REO discount). Thus the present value of the cash flows in the case of a loan default is:

$$PV \{LoanDefaults\} = \sum_{j=1}^S \left[\frac{-C}{(1 + \delta)^j} \right] + \frac{NPDV}{(1 + \delta)^S}, \quad (1)$$

¹⁶The foreclosure timelines are derived from Freddie Mac and Fannie Mae foreclosure data.

where C is taxes, insurance and homeowners' association fees, δ is the monthly discount rate, S is the time until REO sale, and $NPDV$ is the net property disposition value.¹⁷ The determination of the $NPDV$ effectively embeds a simple severity model into the cash-flow structure.

For the modified loan along the default path, the cash flows also include incentive payments paid by the government to the investor during the six-month period that the loan performs.

Cure Cash Flows

The mod and no-mod cure scenarios are evaluated using the same basic framework (Figure 1, branches 1 and 3). Each month, the cash flows are estimated to be: (1) the scheduled principal and interest payment, weighted by the probability the loan will not prepay in that period, and (2) the remaining unpaid principal balance (UPB) of the loan, weighted by the probability that the loan will prepay in that month.

Hence, the basic framework for both branches 1 and 3 in Figure 1 is

$$PV \{LoanCures\} = \sum_{i=1}^T \frac{1}{(1+\delta)^i} \left\{ \begin{aligned} & [UPB_{i-1} - P_i] \left[\prod_{k=1}^{i-1} (1 - SMM_k) - \prod_{k=1}^i (1 - SMM_k) \right] \\ & + [P_i + I_i] \prod_{k=1}^{i-1} (1 - SMM_k) \end{aligned} \right\} + MDLQ(P_0 + I_0), \quad (2)$$

where $MDLQ$ stands for the months delinquent, T is the remaining term of the loan, δ is the monthly discount rate, UPB is the unpaid principal balance, P is the principal at origination, I is the interest rate, and SMM_k is the single month mortality (for prepayment) in month k .

Unmodified loans that cure (branch 3) may have an arrearage that also must be accounted for. Here we make the simplifying assumption that the principal and interest arrearage is paid immediately which is reflected in the $MDLQ(P_0 + I_0)$ term in the present value formula. For the Mod scenario (branch 1), the cash flows reflect the three types of incentives paid to the investor and the cash flow implications of the borrower incentives. These incentives offset some of the reduction in cash flows resulting from the modified loan terms. Servicer incentives are not included in the investor's cash flows and have no direct impact on the NPV Model. The incentives included in the cash flows are:

¹⁷NPDV includes all other costs advanced by the servicer and borne by the investor. For simplicity, the timing of such payments occur at REO disposition.

- (1) **Payment Reduction Cost Share:** 50% of the cost of lowering monthly payments from a level consistent with a 38% DTI to that consistent with the target DTI of 31%, for up to five years. *For example, a borrower with an income of \$1,000 per month and a housing payment (first lien mortgage, taxes, insurance, HOA dues) of \$400 per month would start with a front-end DTI of 40%. The investor would first reduce the mortgage payment by \$20 per month to get the DTI to 38%, then reduce the payment again by \$70 per month to get the DTI to 31%, and Treasury would compensate the investor for half of the \$70, or \$35 per month.*
- (2) **Imminent Default Modification Incentive:** If the borrower is current at the beginning of the trial period (*i.e.*, determined by the servicer to be in imminent default) *and* current at the end of the trial period, the investor will be paid \$1,500 by the HAMP.
- (3) **Borrower Pay-for-Performance Incentive:** Borrowers who make timely monthly payments are eligible to accrue up to \$1,000 of reduction in principal each year for five years. These payments are advanced immediately to the investor as principal curtailment. Because these payments are credited to the borrower through reduced principal, they alter the loan-to-value ratio and therefore have an impact on prepayment and loss severities.¹⁸
- (4) **Home Price Decline Protection Incentive (HPDP):** HPDP is an investor incentive to offset some of the investors' risk of loss exposure due to near-term negative momentum in the local market home prices. The HPDP incentive payments are calculated based upon the following three characteristics of the mortgage loan receiving a HAMP modification:
 - (i) An estimate of the cumulative projected home price decline over the next year, as measured by changes in the home price index over the previous two quarters in the applicable local market (MSA or non-MSA region) in which the related mortgaged property is located;
 - (ii) The UPB of the mortgage loan prior to modification under HAMP; and
 - (iii) The MTMLTV of the mortgage loan based on the UPB of the mortgage loan prior to modification under HAMP.

¹⁸The pay-for-performance incentives are not reflected in the default model because, as noted, modification redefault is assumed to occur six-months after modification and prior to the accrual of any pay-for performance incentives.

NPV Performance

The NPV Model compares the expected cash flows of a loan and its corresponding HAMP modification. For a modification to generate an NPV positive result, the cost of the modification—the reduction in the expected value of scheduled mortgage payments relative to the unmodified loan terms, adjusted for prepayment timing and government subsidies—must be recovered by an increase in the probability of avoiding a costly foreclosure. Grossly oversimplified, the reduction in the default probability caused by the modification, times the expected loss if there is a default (the benefit of the modification), must exceed the cost (net of government subsidies) of providing the modification. The cost of the modification is the probability that the borrower would not have defaulted absent the modification times the change in cash flows from the no-mod-cure scenario to the mod-cure scenario. As this article previously presented, the NPV Model consists of three separate, interacting models: the default probability model, the prepay probability model and the discounted cash-flow model. This section briefly discusses the intuition and key concepts in each of the separate models and follows with some illustrative comparative statics exercises.

NPV Performance General Discussion: Key Concepts

Default model. It is important to emphasize that value within the NPV Model is primarily generated by the change in the default probability resulting from the modification rather than the level of the default probability of the modified loan. Holding constant the change in cash flows, a modification that reduces the default probability by 30 percentage points, from 90% to 60%, generates more value than a modification that lowers the default probability by 5%, from 20% to 15%, though the latter modification has a much lower default probability. The value of the first modification is higher both because the cost of the modification is lower (the no-mod default probability is high) and because the benefit of the modification (the change in the default probability) is higher. An NPV-improving modification might have high-expected re-default rates; therefore a high default probability does not indicate that the investor is made worse through modification.

Prepayment model. The prepayment model dictates when the borrower will voluntarily prepay the remaining principal balance of the loan. The value of receiving that money at a given time—relative to receiving the amortizing payments—depends on the coupon rate of the loan relative to the investor's discount rate. Increasing the rate of prepayment lowers the value of a loan with a coupon higher than the discount rate (because it shortens the time a premium over the market rate is earned) and increases the value of a loan with

a coupon lower than the discount rate (because it allows the released funds to be reinvested at a higher interest rate).

Discounted cash flow model. The cash flow model in the case where the loan performs is a straightforward amortization of the loan according to the terms. However, the default branches of the cash flows—in both the mod and no-mod scenarios—introduce regional variation in foreclosure costs with impacts worth discussing.

The NPV Model includes state-level REO sales discounts and foreclosure timelines because (1) the legal fees and administrative costs associated with foreclosing on a property, (2) the length of time to complete a foreclosure transaction and (3) the amount below the estimated home value a foreclosed property is likely to receive in an REO sale are all expected to vary geographically, based on state foreclosure laws and other factors. Combined with MSA-level home price projections, these parameters determine the value the investor receives upon foreclosure of the home, which forms a crucial threshold in the NPV Model. If the loan balance is below this amount—less a small cushion reflecting the government subsidies to the investor—the NPV test almost never delivers a positive result. When the present value of the home in foreclosure less associated costs exceeds the remaining loan balance, an improvement in the default probability from the no-mod to the mod scenario is highly unlikely to recover the loss in cash flows to the investor from modification, and the modification is therefore almost always NPV negative.

Key variables and comparative statics—the operation of the model. The NPV test is nonlinear in most of its inputs, which makes the influence of specific inputs difficult to directly characterize. To provide some intuition for the behavior of the model under various conditions, we present both an analysis of the NPV accept decisions and a series of comparative static exercises.

The analysis of NPV accepted decisions is based on a sample of 69,625 loan submissions to the NPV Model after October 1, 2010.¹⁹ In this sample, 92.9% of the submissions passed the NPV test. Loans are determined to pass the NPV test if the NPV value is greater than \$0 or in the case of Freddie Mac or Fannie Mae loans greater than negative \$5,000. Table 1 shows the distribution of NPV test pass rates stratified by key variables, and Table 2 shows the results of a logistic regression on NPV outcome using the same data.

¹⁹Servicers could access the NPV Model either through coding the model into their systems or using the NPV transaction portal maintained by the U.S. Treasury Department. These data were taken from loans submitted to the portal and evaluated using the V4 NPV Model. The data were also subject to some reasonableness data edits and restricted to HAMP eligible loans.

Table 1 ■ NPV pass rates by loan attribute.

	NPV Pass ($\geq -5k$ for GSE)		Total	
	Count	Percent	Count	Percent
GSE Flag				
Non-GSE	26,732	89.2%	29,954	43.0%
GSE	37,927	95.6%	39,671	57.0%
Imminent Default Flag				
Imminent Default	11,253	91.1%	12,350	17.7%
60–89 days past due	6,167	88.8%	6,948	10.0%
90+ days past due	47,239	93.9%	50,327	72.3%
Front-end DTI				
≤ 0.35	11,543	96.4%	11,979	17.2%
(0.35, 0.38]	9,204	98.0%	9,396	13.5%
(0.38, 0.41]	8,249	96.1%	8,586	12.3%
(0.41, 0.45]	9,273	94.8%	9,784	14.1%
(0.45, 0.50]	9,059	93.0%	9,737	14.0%
(0.50, 0.55]	6,364	91.7%	6,940	10.0%
> 0.55	10,967	83.1%	13,203	19.0%
Mark-to-market LTV				
$\leq .60$	3,684	80.3%	4,585	6.6%
(.60, .80]	6,292	81.2%	7,745	11.1%
(.80, 1.00]	13,227	92.2%	14,339	20.6%
(1.00, 1.20]	14,553	96.5%	15,078	21.7%
(1.20, 1.40]	9,962	96.4%	10,333	14.8%
(1.40, 1.60]	6,224	97.2%	6,402	9.2%
(1.60, 1.80]	3,933	96.5%	4,074	5.9%
(1.80, 2.00]	2,551	96.6%	2,642	3.8%
> 2.00	4,233	95.6%	4,427	6.4%
FICO				
≤ 540	22,997	93.4%	24,623	35.4%
(540, 600]	19,708	93.3%	21,122	30.3%
(600, 675]	13,956	92.6%	15,068	21.6%
> 675	7,998	90.8%	8,812	12.7%
UPB Before Mod				
$\leq 100,000$	9,937	94.6%	10,505	15.1%
(100,000, 200,000]	24,792	94.2%	26,307	37.8%
(200,000, 300,000]	16,007	93.6%	17,103	24.6%
$> 300,000$	13,923	88.6%	15,710	22.6%
Principal Forbearance Amount				
0	45,653	95.7%	47,682	68.5%
$\leq 100,000$	14,970	91.4%	16,374	23.5%
$> 100,000$	4,036	72.5%	5,569	8.0%

Table 1 ■ Continued.

	NPV Pass ($\geq -5k$ for GSE)		Total	
	Count	Percent	Count	Percent
Freddie PMMS Rate				
$\leq .0425$	10,076	94.0%	10,722	15.4%
(.0425, .045]	7,804	93.5%	8,343	12.0%
(.045, .0457]	12,162	93.0%	13,071	18.8%
(.0475, .05]	32,329	92.3%	35,012	50.3%
$> .05$	2,288	92.4%	2,477	3.6%
Discount Rate Premium				
0	62,652	93.5%	66,997	96.2%
(0, .025)	534	86.6%	616	0.9%
0.025	1,473	73.3%	2,012	2.9%
All	64,659	92.9%	69,625	100

Table 2 ■ Logistic regression: NPV pass.
(Standard errors in parentheses)

Variable	Estimate
Intercept	6.3167*** (0.3466)
GSE Flag	0.7629*** (0.0370)
Delinquency Status	
Imminent Default	-0.1741*** (0.0305)
60-89 days past due	-0.441*** (0.0318)
90+ days past due	0***
Front-end DTI	-0.0399*** (0.0014)
Mark-to-market LTV	0.0295*** (0.0006)
FICO	-0.00115*** (0.0002)
UPB Before Mod (\$K)	-0.00166*** (0.0001)
Principal Forbearance Amount (\$k)	-0.00857*** (0.0003)
Freddie PMMS Rate (bps)	-0.848911*** (0.0677)
Discount Rate Premium (bps)	-0.775715*** (0.0260)

Note: ***Denotes coefficients that are statistically significant at a >99 percent confidence level.

Not surprisingly given the different thresholds for an NPV pass, loans guaranteed by Freddie Mac or Fannie Mae pass at a higher rate than loans on portfolio or serviced on behalf of an investor (95.6% GSE/ 89.2% non-GSE) and the indicator variable for GSE loans has a positive and significant coefficient in the logistic regression results. In the same vein, a higher discount rate applied to long-term cash flows tends to result in lower pass rates because loan modifications extend the period over which cash flows are received. The discount premium (which is applicable only to loans not guaranteed by Freddie Mac or Fannie Mae and allows the discount rate to be increased between 0 and 2.5%) and higher PMMS rates are associated with lower pass rates and have negative coefficients in the logistic regression.

Characteristics associated with higher expected default rates are correlated with higher NPV pass rates. Loans are at higher risk of default as they become more delinquent; loans classified as 90+ days delinquent pass at a higher rate than less delinquent loans. Current and 30-days delinquent loans are eligible for a HAMP modification only if they are determined to be at imminent risk of default. In the NPV Model, these loans are treated as though they are 60–89 days delinquent in order to reflect the imminent default determination.²⁰

The MTMLTV parameter estimated in the logistic regression is positive—suggesting that in general a higher MTMLTV results in a higher probability of an NPV pass. However, the relationship of MTMLTV to pass rates described in Table 1 is nonmonotonic. Lower FICO scores are associated with a higher probability of an NPV pass, but the degree to which this relationship holds varies with MTMLTV.

Loans that require greater financial concessions tend to have lower pass rates. This is most clearly seen in the principal forbearance results in Tables 1 and 2. Loans requiring great amounts of principal forbearance are less likely to be NPV positive. Similarly, the logistic regression results indicate that loans with higher initial front-end DTI levels have a lower probability of an NPV pass; however, Table 1 shows that pass rates are not monotonically decreasing as DTI rises, which we explore in more detail in the comparative statics exercises.

Some of the costs associated with default (including some of the foreclosure and disposition costs) are large and fixed, and so investor losses in foreclosure as a percentage of UPB tend to be larger for lower UPB homes. Similarly, as a

²⁰Perhaps surprisingly, the pass rate for imminent default loans is slightly higher than for loans that are 60–89 days delinquent (91.1% versus 88.8%), and this higher pass rate is also reflected in the logistic regression results. This result reflects other characteristics of imminent default borrowers and the additional investor subsidies offered these loans.

Table 3 ■ Attributes of baseline loan.

Loan Type: 30yr Fixed Rate	Origination Year: 2008
Current Note Rate: 6.5%	Current FICO: 550
Current Income: \$3,600	Delinquency Level: 11 Months
MSA: Miami-Fort Lauderdale-Pompano Beach	MTMLTV: 120%
Pre-Mod Payment: \$1,274	Post-Mod Payment: \$592
Taxes/Insurance/HOA: \$524	Pre-Mod DTI: 50%

proportion of UPB both the investor incentives for imminent default loans and the borrower incentives will be larger for lower UPB homes. This motivates why loans with lower balances (UPB Before Mod) are associated with higher pass rates.

Table 1 shows the distribution of NPV test pass rates stratified by key loan attributes. Key loan attributes are listed in the first column and are divided into subsamples by attribute value. Columns two and three show the number of loans in the subsample that passed the NPV test and the pass rate for the subsample. Columns four and five show the number of loans in the subsample and the subsample share of the full sample.

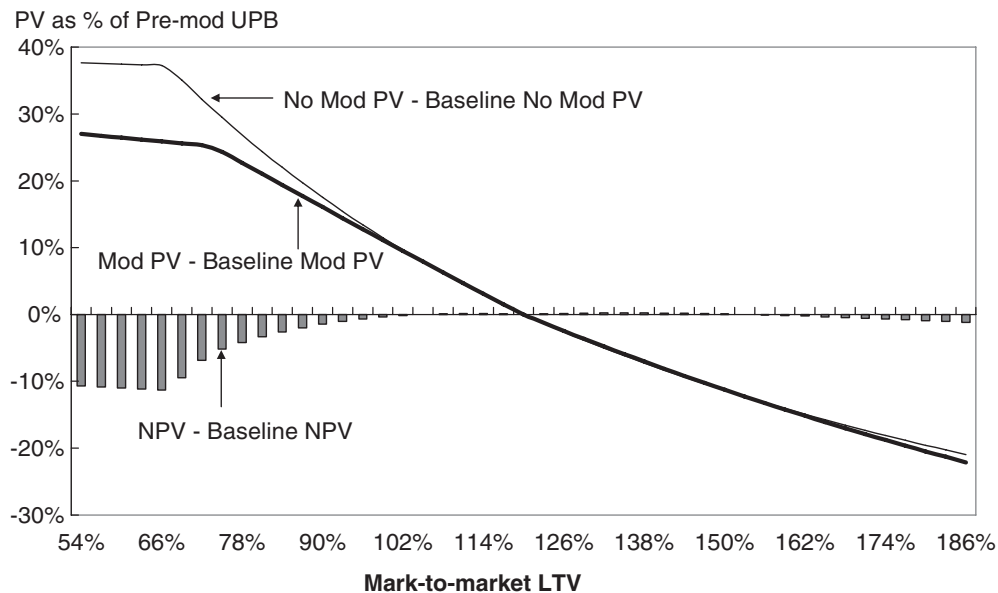
Table 2 shows the result of a logistic regression where the dependent variable is NPV test outcome—pass or not pass. The independent variables are listed in the first column. Column two shows the logistic regression coefficients and standard errors.

Further insight into the workings of the NPV Model can be obtained by illustrating the change in NPV values in response to changes in loan and borrower characteristics in specific examples. For these examples, we use a hypothetical loan that is NPV positive (NPV of HAMP modification = \$19,664). This baseline loan is described in Table 3. The loan is an underwater (MTMLTV = 120) fixed-rate mortgage, originated in 2008 in the Miami area. The HAMP modification for this loan includes a temporary reduction in the note rate to 2%, a term extension to 480 months and forbearance of \$24,840. The new repayment terms reduce the borrower's DTI from 50% to 31% and payment from \$1,274 to \$592.

Table 3 lists key attributes of a hypothetical baseline loan. The loan is used to illustrate the NPV impact of changes to the baseline loan characteristics.

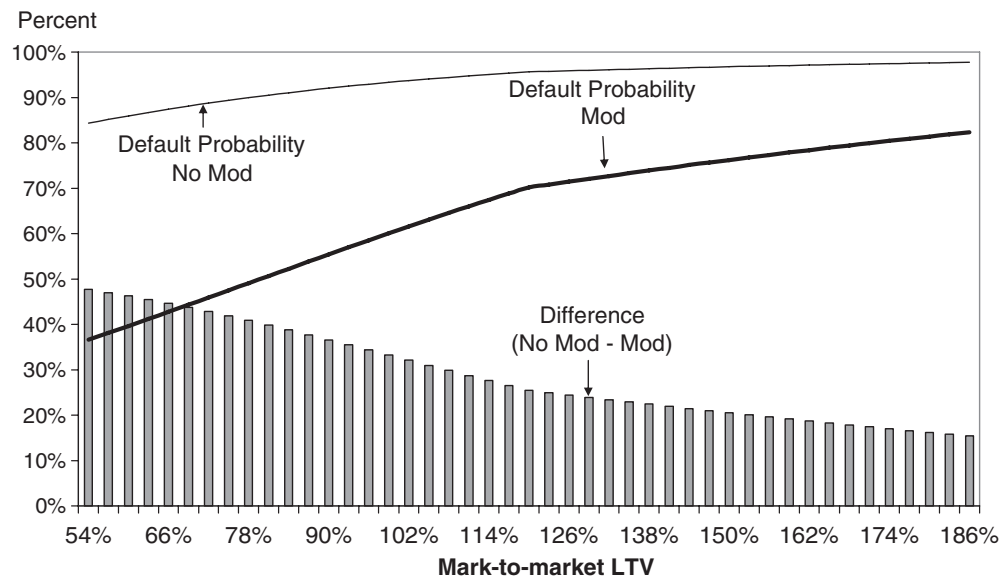
We illustrate the NPV impact of changes to key variables, holding other variables constant. The extent to which the illustrated changes in the dollar value of the NPV test translate into NPV acceptances or rejections in the HAMP program depends upon the composition of loans evaluated for modification.

Figure 2 ■ NPV and cash flows relative to baseline by MTMLTV.



Theoretically, for every dollar change illustrated, a loan exists that may be converted from NPV positive to negative. To reinforce this logical framework, we illustrate the NPV-impacts of changing individual variables in terms of the resulting changes in NPV relative to the baseline loan. The present value cash flows of the unmodified and modified loans and the NPV are set to zero for the baseline loan. The values associated with all other loan characteristics are represented as differences from the baseline values, scaled by the unpaid balance of the loan.

Mark-to-market loan-to-value. As discussed above, mark-to-market loan-to-value (MTMLTV) is an important variable in determining NPV outcomes. MTMLTV is a critical input to the prepayment and default models, reducing likelihood of prepayment and increasing likelihood of default. The MTMLTV is also critical to determining losses that the note holder will incur in the event of foreclosure (essentially whether the value of the home is sufficient to pay off the first-lien unpaid balance and foreclosure costs). Figure 2 shows the impact on the baseline loan's NPV results when this loan's MTMLTV is changed, all other things equal. The illustrated change in MTMLTV reflects adjustments to the value of the home, so that the terms of the modification are not affected. For LTV ranges between 80 and around 150 the NPV of the loan increases with MTMLTV. The intuition of this result is that the cost of the modification is sufficiently high in terms of foregone income that it is profitable only when the modification sufficiently reduces the probability that the investor will face

Figure 3 ■ Default probabilities by MTMLTV.

very substantial principal losses. When negative equity becomes extreme, the NPV can begin falling because the redefault probability becomes extremely high. In the case of this hypothetical loan, NPV relative to the baseline loan falls beyond 150 MTMLTV.

Figure 2 shows the effects of changes in the mark-to-market loan-to-value ratio (MTM LTV) on the present value of a HAMP modification holding other loan characteristics constant. The light and dark lines show the present value of the loan without a modification and the present value with a modification at each MTM LTV level on the horizontal axis. The present values are normalized as a share of premodification unpaid principle balance measured on the vertical axis. The bars show the difference between the modification and no modification outcomes—the net present value of the modification.

Figure 3 illustrates the role of the MTMLTV in the probability of default and redefault. Both the no-modification default and the modification redefault probabilities rise over the entire range shown. In this borrower's case, the spread between the no modification default and the modification redefault narrows over the entire range of MTMLTVs. In other cases, the spread increases over lower ranges of MTMLTV and then begins to decrease at higher MTMLTVs. The general result is that the narrowing of the spread in default probabilities as MTMLTV becomes extreme can lead to declines in the NPV value for high MTMLTV levels.

Figure 4 ■ NPV relative to baseline by FICO and MTMLTV.

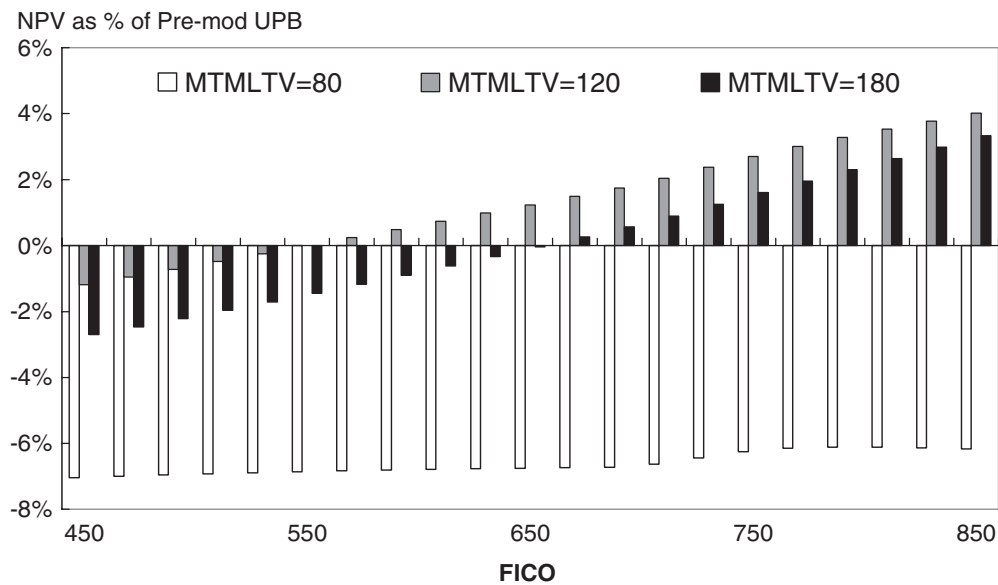
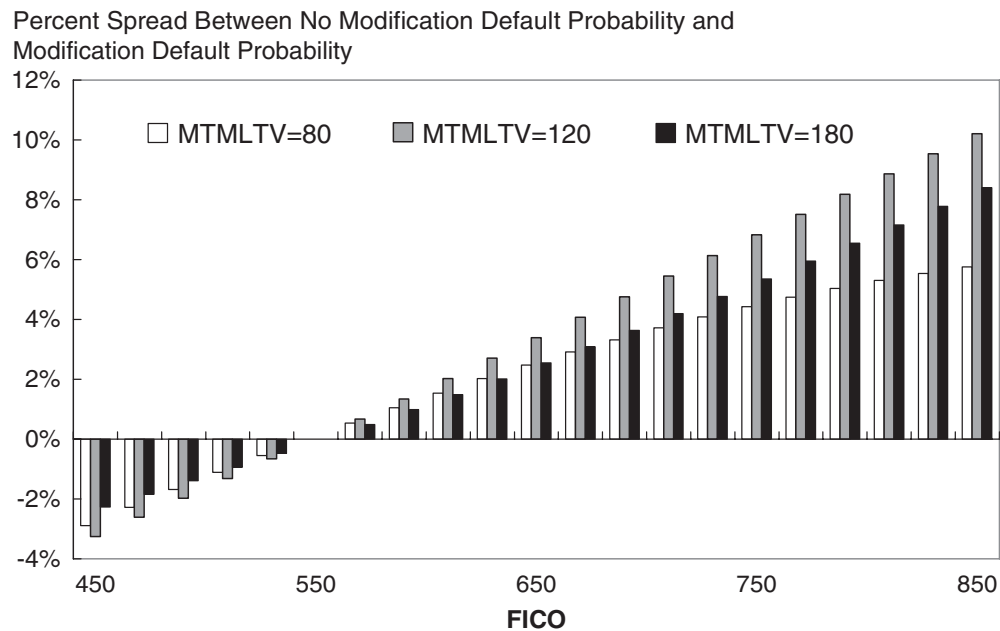


Figure 3 shows effect of changes in mark-to-market loan-to-value ratio (MTMLTV) on predicted default probability with and without a HAMP modification holding other loan characteristics constant. The light and dark lines show the loan's default probability without a modification and with a modification at each MTMLTV level on the horizontal axis. The default probabilities are measured on the vertical axis. The bars show the difference between the modification and no modification default probabilities.

FICO. The impact of the borrower's credit score or FICO on her or his NPV outcome depends heavily on the borrower's equity position. To illustrate, Figure 4 compares NPV outcomes for the hypothetical loan (as a percentage of premodification UPB) across a wide range of FICO scores with three alternative MTMLTV scenarios. For borrowers with positive equity, NPV results are largely insensitive to FICO scores. As shown in Figure 4, NPV remains mostly flat until around 700 and thereafter improves slightly. This is, in part, because FICO effects the NPV calculation only through the default and prepayment models. For borrowers with significant equity, losses are expected to be low and differences in default probabilities do not translate into large changes in NPV.

Figure 4 shows the effect of changes in FICO score on the net present value of a HAMP modification under three MTMLTV scenarios holding other loan characteristics constant. The bars show the net present value of a modification

Figure 5 ■ Default probability spread relative to baseline by MTMLTV and FICO.



(the difference between present value of the loan without a modification and the present value with a modification) at each FICO score on the horizontal axis. The present values are normalized as a share of premodification unpaid principle balance measured on the vertical axis.

For a borrower with negative equity (MTMLTV = 120 and MTMLTV = 180) the NPV is generally increasing with respect to FICO. The increase in NPV over the FICO ranges is partly driven by an increasing spread between the mod and no-mod default probabilities over that range. Figure 5 plots the difference between the no modification and modification default probability spread at the base FICO score (550) and each other FICO point for three MTMLTV scenarios (80, 120 and 180).

Figure 5 illustrates the increasing difference in the spread between the no modification and modification default probabilities as FICO rises. This increasing differential causes the NPV to increase as FICO rises, reflecting the higher probability of a successful (nonredefaulting) modification. Figure 5 also shows that this effect is magnified when the borrower is in a negative equity position but is not monotonically increasing with MTMLTV. The impact of FICO on the spread between no modification and modification default probabilities is quite different across MTMLTV categories. Between FICO = 450 and 850, the spread between the no modification and modification default probabilities

increases by 8.6 percentage points for a $MTMLTV = 80$ loan, compared to 13.5 and 10.6 percentage points, respectively, for $MTLTV = 120$ and 180 loans. This illustrates why the NPV improvement across the FICO spectrum in the $MTMLTV = 80$ scenario is much smaller than for the $MTMLTV = 100$ and 120 scenarios in Figure 4. The fact that the increase in the spread between the no-modification and modification default probabilities is less pronounced at $MTMLTV = 180$ than it is at $MTMLTV = 120$ reflects the fact that at very high $MTMLTV$ levels improvements in default rates are less pronounced because very high $MTMLTV$ borrowers are generally very likely to default.

Figure 5 shows the effect of changes in FICO score on predicted default probability with and without a HAMP modification under three $MTMLTV$ scenarios holding other loan characteristics constant. The bars show the default probability spread (the difference between default probability of the loan without a modification and the default probability with a modification) at each FICO score on the horizontal axis.

Front-end debt-to-income ratio. The original front-end DTI ratio of the borrower determines the monthly payment reduction required to achieve the requisite 31%. Initial DTIs much greater than 31% require large payment reductions and are therefore expensive modifications relative to initial DTIs close to the target. NPV generally declines with DTI above 38%, but in many circumstances NPV is flat or increasing at lower levels of DTI. This interesting result is driven by the dual role DTI plays in the model. Front-end DTI impacts the borrower's default probability in both the modification and the no-modification scenarios. Borrowers with high front-end DTIs have high-predicted default rates, but a high DTI also allows for substantial stabilization through the large payment reduction required to achieve the target DTI. The increased expense of modification for high-DTI borrowers can therefore be counteracted by a substantial decline in the predicted probability of redefault. Conversely, a borrower with a starting DTI close to 31 will receive a small payment reduction that will not sufficiently impact the redefault rate and hence, the result will be a negative NPV (Figures 6 and 7 illustrate).

Figure 6 shows the effect of changes in front-end starting debt-to-income (DTI) ratio on the present value of a HAMP modification holding other loan characteristics constant. The light and dark lines show the present value of the loan without a modification and the present value with a modification at each DTI level on the horizontal axis. The present values are normalized as a share of premodification unpaid principle balance measured on the vertical axis. The bars show the difference between the modification and no modification outcomes—the net present value of the modification.

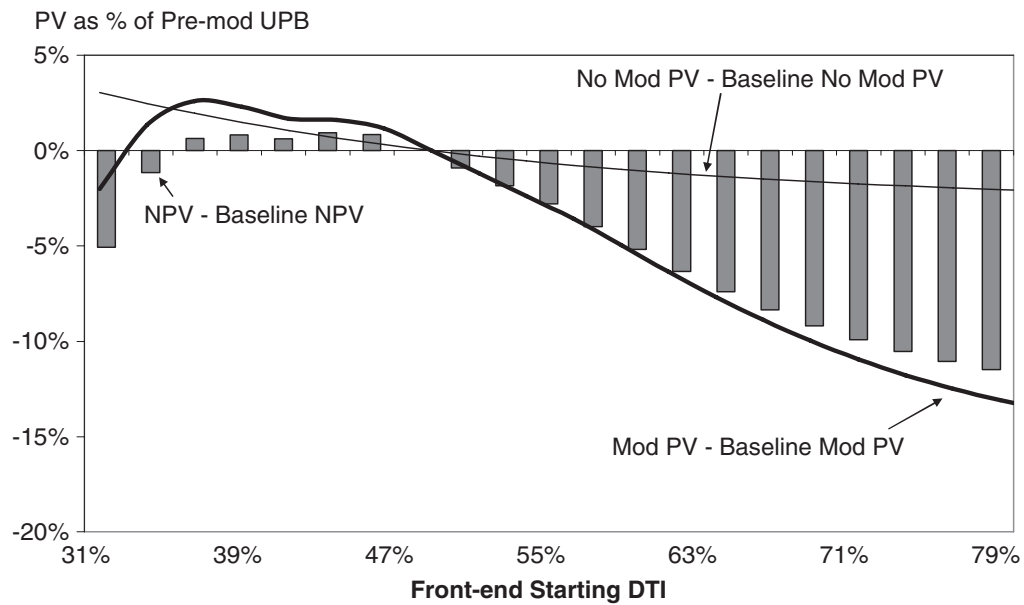
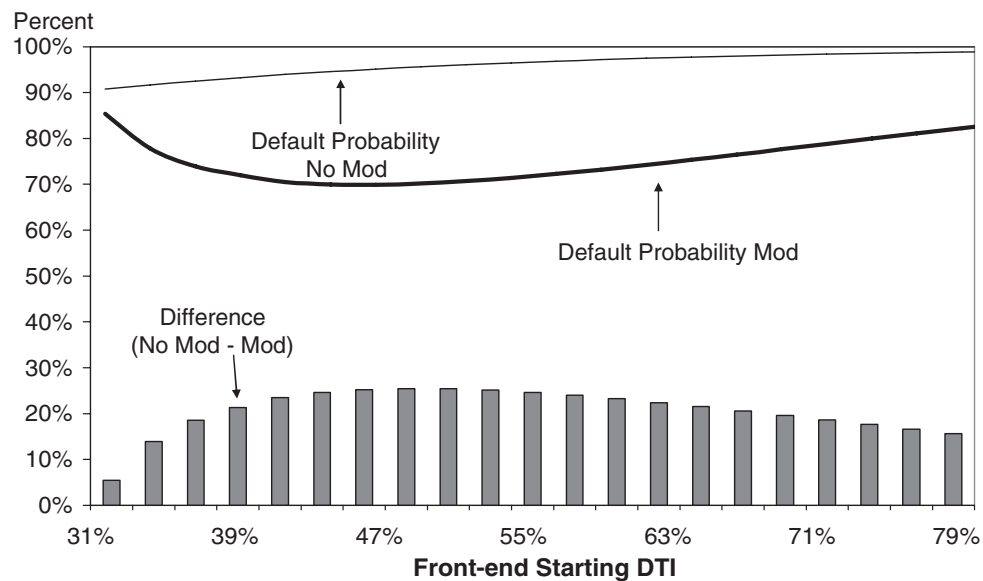
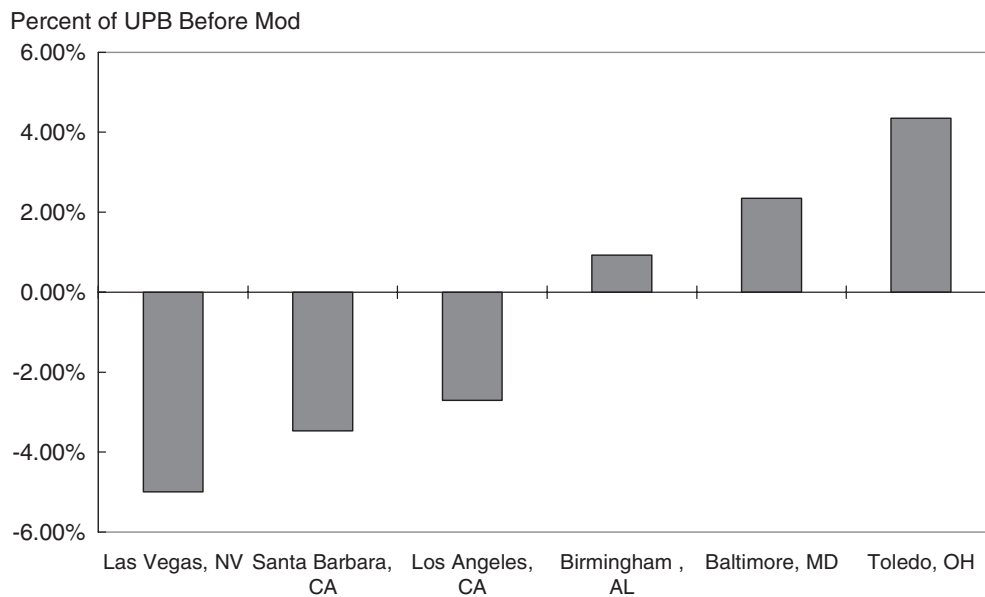
Figure 6 ■ NPV and cash flows relative to baseline by DTI.**Figure 7 ■ Default probabilities by DTI.**

Figure 7 shows effect of changes in front-end starting debt-to-income (DTI) ratio on predicted default probability with and without a HAMP modification holding other loan characteristics constant. The light and dark lines show the loan default probabilities without a modification and with a modification at each

Figure 8 ■ Regional variation in NPV relative to baseline by MSA.



MTMLTV level on the horizontal axis. The default probabilities are measured on the vertical axis. The bars show the difference between the modification and no modification default probabilities.

Geographical variants. The state-level variation in the REO discount values, foreclosure costs and foreclosure timelines, along with the metropolitan statistical area (MSA)-level variation in home price expectations—partially mitigated by home price decline protection (HPDP) payments—generate significant regional variation in NPV outcomes. Figure 8 shows the NPV for the hypothetical loan in different MSAs. Table 4 provides a decomposition of the components that drive the regional variation relative to the Miami area. A number of results stand out. Areas with less negative home price trajectories are more likely to receive modifications because the cost of a delayed foreclosure in the case of redefault is higher in areas with larger projected home price declines. The Home Price Decline Protection Incentive serves to ameliorate the impact of home price forecasts on NPV outcomes and encourage more NPV positive modifications in areas with large projected home price declines.

Higher REO discount values and foreclosure costs and longer foreclosure timelines have a dramatic positive impact on the NPV of modification because each makes the foreclosure more costly. For example, if the hypothetical base loan were located in California rather than in Florida, the shorter foreclosure timelines associated with the California market would reduce the NPV of

modification by 1.09% of premodification UPB. The impact of the REO discount (or “stigma”) is even more dramatic.

Figure 8 shows the effect of a change in property location on the present value of a HAMP modification holding other loan characteristics constant. The present values are normalized as a share of premodification unpaid principle balance measured on the vertical axis. The bars show the difference between the modification and no modification outcomes—the net present value of the modification.

Table 4 shows the effect regional variation has on NPV outcomes. The table reports the result of an analysis in which the NPV for a representative loan located in the Miami-Fort Lauderdale MSA is recalculated substituting regional variables from different MSAs. The regional variables are listed in the first column. Each column to the right reports the change in NPV (as a share of pre-mod UPB) that results from substituting the regional variable values associated with the MSA in the column heading for the values associated with the Miami-Fort Lauderdale MSA. For example, replacing the Miami-Fort Lauderdale MSA Foreclosure and REO Disposition Timeline and Costs with those associated with California (columns three and four) reduces the NPV by 1.09% of pre-mod UPB.

Redefault Model Assessment

For an early assessment of the performance of the redefault model, we used a dataset constructed from HAMP administrative records consisting of 361,577 permanent HAMP modifications. These records included all modifications made permanent between August 2009 and July 2010 for which all inputs to the default model were available. Of these, 20,469 were 90 or more days delinquent six months after becoming a permanent modification, implying about a 5.7% redefault rate in six months.²¹ We used this subset of HAMP loans to evaluate the performance of the default model to date.

Table 5 shows the distribution of loans across relevant characteristics, including initial front-end DTI, vintage, their back-end DTI, MTMLTV, FICO, months past due and the payment change. Disqualification rates (indicating 90+ days delinquency) are also shown by loan characteristic. Note that some fields used

²¹This rate is not directly comparable to HAMP redefault rates published in the OCC and OTS Mortgage Metrics Report. The OCC/OTS report uses a 60 day delinquency rate when reporting on HAMP performance. Furthermore the report only reflects modifications from OCC and OTS regulated institutions.

Table 4 ■ Effect of regional variables on NPV by MSA (Base Region: Miami-Fort Lauderdale-Pompano Beach, FL).

Regional Variables	MSA Name					
	Percent of UPB Before Mod					
	Las Vegas- Paradise, NV	Santa Barbara- Santa Maria- Goleta, CA	Los Angeles- Long Beach- Santa Ana, CA	Birmingham- Hoover, AL	Baltimore Towson, MD	Toledo, OH
Projected Home Price Indices only	-0.58%	-0.55%	-0.10%	-0.44%	-0.41%	-0.98%
Foreclosure and REO Disposition	-0.40%	-1.09%	-1.09%	0.27%	-0.48%	2.10%
Timelines and Costs only						
REO Sale Value Parameters only	-2.85%	-1.40%	-1.40%	1.64%	3.00%	2.62%
Home Price Decline Protection Incentive only	0.08%	0.10%	0.00%	0.13%	0.05%	0.62%
All Corresponding Regional Data Intact	-4.99%	-3.46%	-2.71%	0.92%	2.35%	4.35%

Table 5 ■ Distribution of sample population.

	Loan Count	Share of Sample Population	Share Disqualified at 6-months (90+ days delinquent)
Front-End DTI			
≤0.35	44,378	12.3%	10.7%
(0.35,0.38]	43,247	12.0%	8.5%
(0.38,0.41]	43,541	12.0%	7.1%
(0.41,0.45]	53,493	14.8%	5.7%
(0.45,0.50]	55,458	15.3%	4.5%
(0.50,0.55]	41,133	11.4%	3.7%
(0.55,0.60]	28,025	7.8%	3.2%
(0.60,0.65]	18,675	5.2%	2.6%
>0.65	33,627	9.3%	1.7%
Modification Vintage			
2009:Q3	197	0.1%	15.2%
2009:Q4	21,333	5.9%	4.5%
2010:Q1	141,045	39.0%	4.9%
2010:Q2	161,545	44.7%	6.4%
2010:Q3	37,457	10.4%	6.1%
Back-End DTI			
≤0.40	77,404	21.4%	6.6%
(0.40,0.50]	45,805	12.7%	6.6%
(0.50,0.60]	36,438	10.1%	6.0%
(0.60,0.70]	37,153	10.3%	6.1%
(0.70,1.00]	102,020	28.2%	5.3%
≥1.00	62,757	17.4%	4.0%
Mark-to-Market LTV			
≤1.00	106,802	29.5%	4.9%
(1.00,1.20]	78,153	21.6%	5.7%
(1.20,1.40]	57,630	15.9%	5.6%
(1.40,1.60]	39,323	10.9%	5.7%
(1.60,1.80]	25,915	7.2%	6.0%
(1.80,2.00]	16,836	4.7%	6.1%
>2.00	36,918	10.2%	7.2%
FICO			
≤540	139,874	38.7%	8.5%
(540, 600]	97,225	26.9%	5.5%
(600,675]	71,404	19.8%	3.2%
>675	53,074	14.7%	1.9%
Days Delinquent			
<60	94,509	26.1%	3.2%
≥60	267,068	73.9%	6.5%

Table 5 ■ Continued.

	Loan Count	Share of Sample Population	Share Disqualified at 6-months (90+ days delinquent)
Payment Change			
$\geq -10\%$	27,750	7.7%	11.4%
$[-20\%, -10\%)$	44,322	12.3%	8.9%
$[-30\%, -20\%)$	56,291	15.6%	7.3%
$< -30\%$	233,214	64.5%	4.0%
All	361,577	100.0%	5.7%

in the regression, such as the FICO score, were not required at the inception of the program and hence early modifications may be disproportionately excluded from this sample.

Table 5 shows the distribution of key variables used to evaluate the redefault performance of an early sample of HAMP modifications. Key loan attributes are listed in the first column and are divided into subsamples by attribute value. Columns two and three show the number and share of loans in the subsample. Column four shows the share of each subsample that missed three payments within six months of becoming a permanent modification.

At this early stage, the initial performance of modified loans can provide some insight into whether the predicted relationships between the variables are qualitatively consistent with the observed drivers of redefault in the HAMP program. The results are mostly monotonic and directionally consistent with the NPV redefault model, providing support for the underlying default specification. Figure 3 shows an increasing probability of default (after modification) as MTMLTV increases; this relationship is evident in the results. All else equal, we see a pattern of higher default probability in higher MTMLTV ranges. Similarly, as described in Figure 5, high FICOs result in lower redefault probabilities. The effect of delinquency status at time of modification shows the same basic structure as the redefault model: borrowers who have never been delinquent or came into the program just after becoming delinquent have a lower chance of redefaulting than borrowers who are two or more periods delinquent when they entered the program.

Table 6 shows the results of a logistic regression of an indicator variable for modification disqualification (indicating 90+ day delinquency) on the

Table 6 ■ Logistic regression: 90+ delinquency 6 months postmodification.
(Standard errors in parentheses).

Variable	Estimate
Intercept	−4.5487*** (0.0596)
Front-end DTI	
< = 0.35	2.0066*** (0.0449)
(0.35, 0.38]	1.7499*** (0.0456)
(0.38, 0.41]	1.551*** (0.0461)
(0.41, 0.45]	1.3061*** (0.0461)
(0.45, 0.50]	1.0363*** (0.0468)
(0.50, 0.55]	0.8084*** (0.0496)
(0.55, 0.60]	0.6391*** (0.0542)
(0.60, 0.65]	0.4254*** (0.0624)
>0.65	0
Mark-to-market LTV	
< = 1.00	−0.5976*** (0.0252)
(1.00–1.20]	−0.3615*** (0.0259)
(1.20–1.40]	−0.3164*** (0.0276)
(1.40–1.60]	−0.2592*** (0.0301)
(1.60–1.80]	−0.1863*** (0.0336)
(1.80–2.00]	−0.1629*** (0.0386)
>2.0	0
FICO	
< = 540	1.3763*** (0.0344)
(540, 600]	0.9517*** (0.0358)
(600, 675]	0.4637*** (0.0389)
>675	0

Table 6 ■ Continued.

Variable	Estimate
Modification Vintage	
2009:Q3	0.867*** (0.2050)
2009:Q4	−0.3445*** (0.0399)
2010:Q1	−0.253*** (0.0253)
2010:Q2	0.0234 (0.0243)
2010:Q3	0
Days Delinquent	
<60	−0.5128*** (0.0208)
>= 60	0

Note: ***Denotes coefficients that are statistically significant at a >99% confidence level.

covariates used in the NPV default model. We have also included an additional control for the vintage of the loan.

Table 6 shows the results of a logistic regression where the dependent variable is 90 days delinquent within six months of becoming a permanent modification. The independent variables are listed in the first column. Column two shows the logistic regression coefficients and standard errors.

The one area where qualitative results suggest a meaningful difference between the empirical results and the structure of the redefault model is front-end DTI. Because all HAMP mods produce a DTI of 31%, the change in DTI is completely determined by the pre-mod DTI. As discussed above, the NPV redefault model is nonlinear in front-end DTI (Figure 7) with redefault increasing at high pre-mod DTI levels. Instead, the early empirical evidence reported in Table 6 shows a monotonic relationship suggesting that the change in DTI dominates the starting level of DTI as a driver of default. As modifications continue to age, this relationship will become clearer and the structure of the redefault models may be modified to reflect this.

It also should be emphasized the early program data will not reveal whether the redefault model is accurately predicting the level of redefault probability. The redefault model in the NPV tool assigns a predicted lifetime redefault probability, whereas the data currently available for evaluation consist of only

the first several months after a modification successfully completes its trial and is made permanent. Moreover, because HAMP trials can be cancelled for reasons other than nonpayment, we can be sure a HAMP cancellation is due to nonpayment only after the modification has completed the trial payments, seasoning for at least three months. Finally, the limited seasoning of this sample precludes capturing the impacts of mortgage rate step-ups after the five-year initial mod period. The predicted default levels are therefore not expected to align with the observed redefault rate at this point.

Concluding Thoughts

The HAMP program was developed in recognition of the need for a standardized process for the evaluation and modification of at-risk homeowners. The NPV Model has played an important role toward that end. HAMP has changed the landscape of loan modifications—encouraging the use of payment-reducing modifications for borrowers with serious affordability issues. Similarly, HAMP has encouraged the systematic evaluation of borrowers using well-documented, defensible models. This article represents the initial output of a continuing effort to evaluate the key components of the HAMP NPV Model; our findings suggest that, to date, HAMP borrowers' redefault behavior has been broadly consistent with the predictions of the NPV Model's default model. Going forward, we expect that NPV evaluation will remain part of the standard servicing toolkit and that NPV modeling will continue to improve as the results of HAMP and other modification experiences improve our understanding of the behavior of at-risk homeowners and as information systems broaden the scope and richness of feasible inputs. Ultimately widespread use of well-specified NPV models will result in fewer missed opportunities for value-enhancing modifications, fewer nonvalue-enhancing modifications and better outcomes for investors, homeowners and servicers. This may be one of the enduring legacies of HAMP.

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