Does Reducing 'Underwaterness' Prevent Mortgage Default? Evidence from HAMP PRA*

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Abstract

The Home Affordable Modification Program's Principal Reduction Alternative (HAMP PRA) is a government-sponsored program to reduce the monthly mortgage payments and mortgage balances of struggling borrowers who are 'underwater', i.e. whose mortgage balance exceeds their home value. We use administrative data to examine the impact of principal forgiveness – a permanent mortgage balance reduction – on subsequent mortgage delinquency. The program's rules for allocating forgiveness imply two kinks (discontinuities in the first derivative) in the function that determines the amount of principal reduction as a function of the borrower's initial negative equity level, *ceteris paribus*. On one side of each kink, increasing underwaterness leads on the margin to a dollar-for-dollar increase in principal reduction (holding the payment reduction constant by replacing other forms of payment reduction with principal reduction); on the other side of the kink, increasing underwaterness does not change the mortgage modification on the margin. The impact of principal reduction can therefore be identified by exploiting the quasi-experimental variation in principal reduction using a regression kink design (RKD), comparing the relationship between underwaterness 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 3.8%; we estimate that it would have been 4.7% in the absence of principal reduction, which averaged 29% of the initial mortgage balance.

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1 Introduction

There are more than 50 million first-lien residential mortgages in the U.S., with a total balance exceeding $10 trillion. Mortgages represent by far the largest liability for U.S. households.

From the 4th quarter of 2006 through the first quarter of 2009, falling home prices reduced U.S. home equity by nearly $5 trillion. As of the fourth quarter of 2012, an estimated 10.4 million homes had negative equity or were 'underwater' (Corelogic, March 2013), with mortgage balances on those homes exceeding home values. Negative equity on these underwater homes exceeded $800 billion at its peak, but had fallen to about $628 billion by the fourth quarter of 2012. (Corelogic, March 2013) Research has raised concerns that this negative equity may be associated with reduced mobility (Ferreira, Gyourko, and Tracy, 2010, 2013)[1], an inability to refinance mortgages into the recent low interest rate environment (Boyce, Hubbard, Mayer, and Witkin, 2012), and reduced consumption (Mian and Sufi, 2011; Dynan, Spring 2012).

During the same period that home prices fell and negative equity increased, mortgage delinquency rates rose rapidly. The share of active mortgages in 90+ day delinquency or 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, though it has since fallen to 6.4 percent in the first quarter of 2013. (Mortgage Bankers Association, May 2013) The possible link between negative equity and mortgage delinquency is therefore of natural interest.

This paper uses administrative data on the Home Affordable Modification Program's (HAMP's) Principal Reduction Alternative (PRA) to examine the impact of principal reduction on subsequent mortgage default, as measured by 90-day delinquency and consequent disqualification from HAMP. For lenders and policy makers, this information is of natural interest in designing mortgage modifications and in understanding the risks arising from various combinations of mortgage characteristics. (Das, 2012) For economists,

[1]This result has been contested in Schulhofer-Wohl (2012).

these findings contribute to the literature evaluating borrowers' default decisions in the context of negative equity (Foote, Gerardi, and Willen, 2008; Deng, Quigley, and van Order, 2000).

Several papers have examined the relationship between negative equity and mortgage default since the start of the housing crisis (Bajari, Chu, and Park, 2010; Bhutta, Dokko, and Shan, 2010; Fuster and Willen, 2012; Ghent and Kudlyak, 2011; Tracy and Wright, 2012; Haughwout, Okah, and Tracy, 2010). One strategy employed in the research is to use loan-level performance data (Bajari, Chu, and Park, 2010; Bhutta, Dokko, and Shan, 2010) and exploit variation in negative equity arising from changes in state- or zip-code-level home price indexes. Because certain information – such as income – is available only at the time of origination, structural methods are used to control separately for income shocks using available measures of local labor market conditions (e.g., state- or county-level unemployment).

The major challenge inherited by these research designs in the existing literature 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. Variation in negative equity driven by initial downpayment, mortgage terms, cash-out refinancing, or time of purchase may be associated with unobservable borrower characteristics. Moreover, borrowers with different levels of negative equity because they invested during different stages of the housing market may have been unobservably different.[2] As a result, using these sources of variation in negative equity may not reveal the causal relationship between negative equity and mortgage default.

Several papers have looked more directly at the role of principal reduction in modification performance by comparing the default rates on non-HAMP modifications with

[2]For example, there is evidence that income was less-stringently documented as home prices accelerated (Keys, Mukherjee, Seru, and Vig, 2010; Jiang, Nelson, and Vytlacil, 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, Lee, Tracy, and van der Klaauw, September 2011).

and without principal reduction. (Haughwout, Okah, and Tracy, 2010; Agarwal, Amromin, Ben-David, Chomsisengphet, and Evanoff, 2011) However, in these data, it is not clear what unobservable criteria (including on variables like pre-modification DTI and FICO that are observable in our data) affected who received principal reduction and how much they received. Absent perfect controls, the impact of these unobservable factors on mortgage default or delinquency may be misidentified as coming from negative equity.

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. The structure of HAMP PRA allows cleaner identification of the relationship between principal reduction and mortgage default.

The Home Affordable Modification Program (HAMP) Principal Reduction Alternative (PRA) is a government program to provide payment reduction and principal reduction to troubled mortgage borrowers whose mortgages are underwater. The HAMP program is implemented by mortgage servicers, who can choose to participate. All potentially eligible 60-day delinquent borrowers must receive a notice containing information on applying for relief through HAMP. HAMP applicants provide information about their income to calculate their mortgage debt-to-income ratio (DTI), a measure of the affordability of a mortgage payment; an automated appraisal system is used to estimate the borrower's home value and with it their loan-to-value (LTV) ratio, a measure of negative equity. The terms of a HAMP PRA modification are determined by the borrower's initial DTI, LTV, and a servicer-specific LTV target (usually 115% or 100%).

HAMP 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. Some servicers restrict the maximum principal reduction amount to 30% of the

pre-modification unpaid balance. If principal reduction 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. Servicers evaluate modifications to determine their net present value (NPV) to the lender before offering those modifications to borrowers.

HAMP PRA program rules imply kinks – discontinuities in the first derivative – in the function that determines the amount of principal reduction as a function of the borrower's initial negative equity, *ceteris paribus*. In a specific pre-modification LTV range, a higher LTV generates a modification with more principal reduction (and less use of the other, less generous modification steps). In this range, every additional dollar of unpaid balance generates an additional dollar of principal reduction.[3] However, for LTVs above this pre-modification LTV range, a higher LTV has no effect on the mortgage modification terms. We refer to the pre-modification LTV at the border between these ranges as the kink. The pre-modification LTV at which this kink occurs varies from loan to loan based on the affordability (DTI) of the initial mortgage and on the servicer-specific LTV target.

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

These kinks allow the impact of principal reduction to be identified by exploiting the quasi-experimental variation in principal reduction from a regression discontinuity design (RDD) (Hahn, Todd, and Van der Klaauw, 2001; Lee and Lemieux, 2010), or more specifically a regression kink design (RKD) (Florens, Heckman, Meghir, and Vylacil, 2009; Card, Lee, Pei, and Weber, November 2012).[4] We estimate the impact of principal reduction on mortgage default by comparing the relationship between LTV and default

[3]This is the pre-modification LTV range where reducing negative equity to its LTV target alone is insufficent to reach the affordability target, namely DTI of 31%.

[4]Provided the region around the kink is small enough and assignment on either side of the kink is quasi-random, observable and unobservable variables should be the same for observations on either side of the kink. As a result, additional controls are unnecessary and concerns about omitted variables are lessened.

on either side of the kink.

Servicers are required to implement HAMP PRA based on explicit, observable, objective criteria, which we observe and can control for. This precludes, or at least limits, servicer-based selection. Borrowers cannot observe their DTI or LTV with great precision, are unable to effectively manipulate LTV, and will typically not know their servicer's LTV target. Borrowers' difficulty in determining on which side of the kink they will fall at the time of HAMP application limits the scope for borrower-based selection into different principal reduction amounts. Finally, because we have loan-level information on the borrower at the time of HAMP application, we can explicitly control for variables (such as borrower DTI and FICO) that in other studies are unobservable or observable only at origination.

We find that principal reduction reduces subsequent rates of delinquency. Among HAMP PRA participants in our sample, 3.8% become at least 90 days delinquent (at which point they are dropped from the program) per quarter on average. Our estimates suggest that this rate would have been 4.7% (95% confidence interval (CI): 4.3% to 5.2%) had these borrowers received modifications with no principal reduction (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 29% reduction in the mortgage balance. The first cohort of PRA modifications in our sample (originated 2011:Q1) had a cumulative default rate of 31%; we estimate that their default rate would have been 40% (95% CI: 36% to 44%). The cumulative default rate in the sample (overall default rate thus far) is 15.8%; we estimate that it would have been 19.2% (95% CI: 17.8% to 20.9%).

These results are robust to a variety of specifications and are present in various sub-samples of the data. Furthermore, separate analyses of the two kinks yield similar estimates of the impact of principal reduction on subsequent default. We find some evidence that the impact of principal reduction on default abates somewhat for later

cohorts.

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 subsidizes servicers and lenders to modify mortgages according to the terms of a HAMP modification. At the beginning of the program, participating services 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 covering nearly 90% of the mortgage market elected to participate in the HAMP program, though not all of these services elected to participate in the Principal Reduction Alternative (PRA).

HAMP requires services to send borrowers a letter with information on applying for a HAMP mortgage modification when they become 60-days delinquent.[5] To be eligible for the HAMP program, borrowers must have a mortgage DTI over 31%, live in the mortgaged home, and have an unpaid balance below $\$729,750$; however, larger balances are allowed for multi-family properties if the borrower lives in one of the units.[6] Borrowers must sign a hardship affidavit, under penalty of perjury, stating that they have experienced a hardship and are unable to make their current mortgage payments.

When borrowers apply for HAMP, they provide information about their income, which is used to determine the debt-to-income (DTI) ratio, the measure of affordability used by HAMP. DTI measures the fraction of the borrower's pre-tax income that goes to monthly

[5]Non-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.

[6]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 reduction is included. We exclude PR recipients in Tier 2 from our sample.

first-lien mortgage payments, real estate taxes, homeowner's insurance, and condominium or homeowner's association dues. Temporary income – such as from unemployment insurance – is excluded from the gross income calculation. An automatic appraisal system calculates home value, which is used to determine the loan-to-value (LTV) ratio – the balance on the first mortgage divided by the home value – which is the measure of home equity used by HAMP. Updated FICO scores are pulled from credit bureaus.

Two modifications are commonly offered under HAMP: 'Standard' HAMP and HAMP PRA. Servicers use an NPV model to compare the expected discounted cash flows lenders would receive under each potential modification and without a modification. The 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. Servicers typically offer borrowers the option that yields the highest NPV, 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).[7] Not all HAMP-participating servicers participate in HAMP PRA, and some loans serviced by HAMP PRA-participating servicers 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 new, lower mortgage payments and produce any required documentation (e.g., occasionally certain income documents are not collected up front). If borrowers fail to produce this documentation or go delinquent during this period, they fail out of the trial modification. At this point, the mortgage

[7]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.

reverts to its pre-modification terms and delinquency or foreclosure proceedings can continue; the borrower may also be evaluated for a non-HAMP modification. 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 delinquency or foreclosure proceedings can be re-initiated; mortgage terms will nominally remain as specified in HAMP unless the servicer elects to further modify the borrower.

To encourage participation in HAMP, the government provides subsidies to participating lenders, servicers, and borrowers. Servicers receive an up-front fee for each permanent modification ($400-$1,600) plus up to $1,000 per year for each year that a modification remains in the program (up to 5 years). Borrowers receive up to $1,000 per year if the borrower remains in the program (up to 5 years), applied directly to their unpaid balance, as long as they are not delinquent. Lenders receive half of the borrower payment reduction between 38% and 31% DTI while the borrower is in the program (up to 5 years). These payments apply to all HAMP modifications, both 'standard' HAMP and HAMP PRA. Investors also receive subsidies for writing down principal, which we cover in the section below.

2.1 'Standard' HAMP

The standard HAMP modification is designed to bring the borrower's mortgage payment to an affordable level, defined in this program as a post-modification DTI of 31%. Borrowers with a pre-modification DTI below 31% are ineligible for HAMP; borrowers with a pre-modification DTI above 31% have their post-modification DTI reduced to 31%. Past-due fees are waived and past-due interest is capitalized into the unpaid mortgage balance. The standard modification does not permanently reduce the mortgage balance and is not the focus of this paper.

The standard HAMP modification is summarized in Table 1. The payment reduction

in the standard modification is achieved first by reducing the mortgage interest rate until the payment hits the affordability target of 31% DTI or the rate hits the 2% floor. If further payment reduction is needed to reach 31% DTI, the mortgage term is extended in monthly increments until the payment reaches 31% DTI or the term reaches 40 years. If further payment reduction is needed to reach 31% DTI, then principal forbearance is used as needed to reach 31% DTI (which is equivalent to reducing the interest rate as needed to zero). Servicers may cap principal forbearance at 30% of the borrower's principal balance; if the payment target cannot be met using 30% principal forbearance, the borrower can be turned down. The mortgage terms remain unchanged for five years; after five years, if the modified mortgage rate is below the Primary Mortgage Market Survey (PMMS) 30-year fixed-rate-mortgage rate that prevailed at the time of the modification (the rate cap), the mortgage rate rises one percentage-point per year until it reaches the rate cap, at which point it becomes fixed. Borrowers with modification rates over the rate cap retain their modification rate for the duration of the modified mortgage term.

2.2 HAMP PRA

The HAMP Principal Reducation Alternative (PRA) modification is designed to bring the borrower's mortgage payment to an affordable level – to a post-modification DTI of 31%, like 'standard' HAMP – in a way that prioritizes principal reduction, as summarized in Table 1. Standard HAMP and HAMP PRA therefore involve the same payment reduction, though PRA modifications achieve at least some of that payment reduction by reducing the principal balance. Servicers set their own LTV targets for HAMP PRA. Servicers covering roughly three-quarters of our sample use a 115% target, and the remaining use 100%.[8]

[8]Some borrowers are ineligible for PRA, including borrowers with an LTV below the target, borrowers with loans guaranteed by Fannie Mae or Freddie Mac, and loans in securitization pools that explicitly prohibit principal reduction. While 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 services with volume so low we could not ascertain their LTV target with certainty, and one large servicer who uses a principal-reduction allocation method that does not generate the kink

Payment reduction is achieved by reducing mortgage principal until the borrower's payment achieves the affordability target (31% DTI) or the borrower's LTV reaches the servicer's target, whichever requires less principal reduction.[9] Servicers with an LTV target of 100% have also chosen to apply a 30% cap on the amount of principal reduction as a share of the principal balance. If the affordability target of 31% DTI is reached using principal reduction, the borrower's LTV remains at or above the servicer's LTV target, and there are no further steps in the modification; in this range, increasing pre-modification LTV on the margin would have no effect on the mortgage modification. If the affordability target of 31% DTI has still not been reached when LTV has been reduced to its target level, then the modification proceeds using the steps from a 'standard' HAMP modification. The interest rate is reduced as needed to reach 31% DTI or to 2%, whichever comes first; then if needed, 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. In the range where principal reduction alone is insufficient to achieve the servicer's LTV target, increasing pre-modification LTV on the margin would lead to more principal reduction (a larger percent change in LTV) and correspondingly less temporary rate reduction, term extension, or forbearance, whichever is the last step in the modification reached by that borrower.

Nominally, the principal reduction is phased in over three years in three equal-sized increments. However, if the borrower wishes to sell or refinance the house at any time, they need repay only the post-modification loan balance, which incorporates the full forgiveness amount. If the borrower becomes more than 90 days delinquent and is kicked out of the HAMP program, their balance is reduced by only the portion of the principal

we exploit for identification.

[9]One major servicer implements HAMP PRA using a different formula. HAMP provides flexibility for servicers to lower payments below 31% DTI. This servicer reduces the mortgage principal until the borrower's LTV reaches the servicer's target, regardless the DTI reduction. If the LTV target is achieved at a DTI above the affordability target required by HAMP, the standard HAMP waterfall is employed to achieve the remainder of the payment reduction. This servicer is excluded from this analysis because the kinks we study here are not present in their principal reduction formula.

reduction that they 'earned' from their time in the program, not the full amount. Any remaining PR that has not been vested is converted to forbearance.

To provide lenders with an incentive to participate in HAMP PRA, principal forgiveness is subsidized. Originally, the subsidy was \$0.21 per dollar of principal reduction in the LTV range above 140%, \$0.15 per dollar of principal reduction in the LTV range between 115 % and 140%, and \$0.06 per dollar of principal reduction in the LTV range between 105% and 115%. These lender subsidies for principal reduction were tripled by the government in March 2012 to encourage lender participation in the program, so that current subsidies now range from \$0.18 to \$0.63 per dollar of principal reduction. Borrowers who are more than 6 months delinquent at the time of modification receive the lowest level of subsidy, regardless the LTV of the principal forgiven. Subsidies are granted over three years as principal is nominally forgiven/earned (not up-front), or upon borrower prepayment; as a result, lenders receive no subsidy on borrowers who default immediately.

Table 1: 'Standard' HAMP and HAMP PRA Modifications

Standard HAMP	HAMP PRA
No reduction in mortgage balance	*Reduce mortgage balance* as needed to reach the lesser of underwaterness target (typically 115% LTV) and affordability target (31% DTI)
If previous step insufficient to reach 31% DTI, then *reduce interest rate* down to 2% as needed to reach 31% DTI.	
If previous step insufficient to reach 31% DTI, then *extend loan term* to up to 40 years as needed to reach 31% DTI.	
If previous step insufficient to reach 31% DTI, then *foerbear principal* as needed to reach 31% DTI. (equivalent to zero rate)	

2.3 Identification

The structure of the HAMP PRA modification includes two kinks that we exploit for identification. On one side of each kink, the principal reduction amount varies with the borrower's LTV, while on the other side, the modification structure is invariant to LTV. While HAMP PRA loans differ in their pre-modification affordability (as measured by DTI), all HAMP PRA modifications have the same post-modificiation affordability level.[10] Post-modification LTV (or equivalently, the amount of principal reduction (PR)) 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) as follows:[11]

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

Limiting the sample to loans with a pre-modification LTV above their servicer's target and taking logs yields:

$$\begin{aligned} \ln(1 + \text{PR}) = \quad & \min(\ln \text{pre-modification LTV} - \ln \text{target LTV}, \\ & \ln \text{pre-modification MDTI} - \ln \text{target MDTI}). \end{aligned} \tag{2}$$

The amount of principal reduction (PR) is a kinked function of the borrower's pre-

[10] The total DTI target is 31% on all loans. Borrowers may differ in their ability to pay 31% of income for housing based on other credit card debts, student loan payments, health expenditures, or other obligations.

[11] The servicer LTV target is 115% for 75% of loans and 100% for the remaining 25%. DTI 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.

modification LTV. The location of the kink depends on the pre-modification MDTI, the servicer's target LTV and the borrower's target MDTI. The pre-modification LTV at the kink equates the two arguments of the min function in equation (1):

$$\text{pre-modification LTV}^{\star} = \text{target LTV} \times \frac{\text{pre-modification MDTI}}{\text{target MDTI}} \tag{3}$$

For pre-modification LTVs below LTV*, the amount of principal reduction included in the modification is increasing in pre-modification LTV (and the amount of temporary rate reduction or term extension is decreasing in pre-modification LTV); for pre-modification LTVs above LTV*, the mortgage modification terms do not depend on the pre-modification LTV:

$$\begin{aligned} \frac{d\ln(1+\text{PR})}{d(\ln(\text{pre-modification LTV}))} &= 1 \qquad \text{if pre-modification LTV} < \text{pre-modification LTV}^{\star} \\ &= 0 \qquad \text{if pre-modification LTV} > \text{pre-modification LTV}^{\star} \end{aligned} \tag{4}$$

A second kink is present at the 30% principal reduction (PR) cap for roughly one-quarter of mortgages with servicers that apply this cap.[12] The cap lowers pre-modification LTV* in equation (5) for high-DTI, high-LTV borrowers. Below the pre-modification LTV* implied by this cap, increasing LTV increases principal reduction; above this point, the modification is unchanged by increasing LTV.

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

$$\begin{aligned} \text{PR} &\equiv \frac{\text{pre-modification LTV}}{\text{post-modification LTV}} - 1 \\ &= \max\left(0, \min\left(\frac{\text{pre-modification LTV}}{\text{target LTV}}, \frac{\text{pre-modification MDTI}}{\text{target MDTI}}, 10/7\right) - 1\right). \end{aligned} \tag{5}$$

Limiting the sample to loans with LTV above their servicer's target and taking logs yields:

$$\begin{aligned} \ln(1+\text{PR}) = \quad & \min(\ln 10 - \ln 7, \ln \text{pre-modification LTV} - \ln \text{target LTV}, \\ & \ln \text{pre-modification MDTI} - \ln \text{target MDTI}). \end{aligned} \tag{6}$$

The kinked structure of the problem allows us to examine the impact of principal reduction while controlling separately (and even non-parametrically) for pre-modification LTV, pre-modification MDTI, and target LTV, and target MDTI. This suggests the following basic regression to predict re-default:

$$\begin{aligned}\Pr(\text{Default}) = f(\alpha &+ \beta_{\text{PR}} \ln(1+\text{PR}) \\ &+ \beta_{\text{LTV}}(\ln \text{pre-modification LTV} - \ln \text{LTV target}) \\ &+ \beta_{\text{DTI}}(\ln \text{pre-modification MDTI} - \ln \text{MDTI target}) \\ &+ \beta_X X + \varepsilon)\end{aligned} \tag{7}$$

The principal reduction term in the first row of equation (7) is the minimum of the terms found in the second (the negative equity term) and third rows (the affordability term). The regression examines the impact of principal reduction while controlling separately for the variables that determine it. 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 at determines the amount of principal reduction the borrower receives. It is straightforward to allow for an interaction of the negative equity and affordability terms, so long as this interaction doesn't take the kinked form of a minimum.

As is standard in a regression 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.

We control for the number of quarters that have passed and the servicer's LTV target in every specification. Additional controls including servicer dummies, calendar quarter dummies, LTV target dummies, ln(pre-modification DTI), geographic information, income, balance, fico, and NPV test outcomes can be added, and a variety of para-

metric specifications can be included. Furthermore, we can perform the analysis in the neighborhood around the kink, where:

$$\text{abs}\ln\left(\frac{\text{pre-modification LTV}}{\text{pre-modification LTV}^{\star}}\right) < k \tag{8}$$

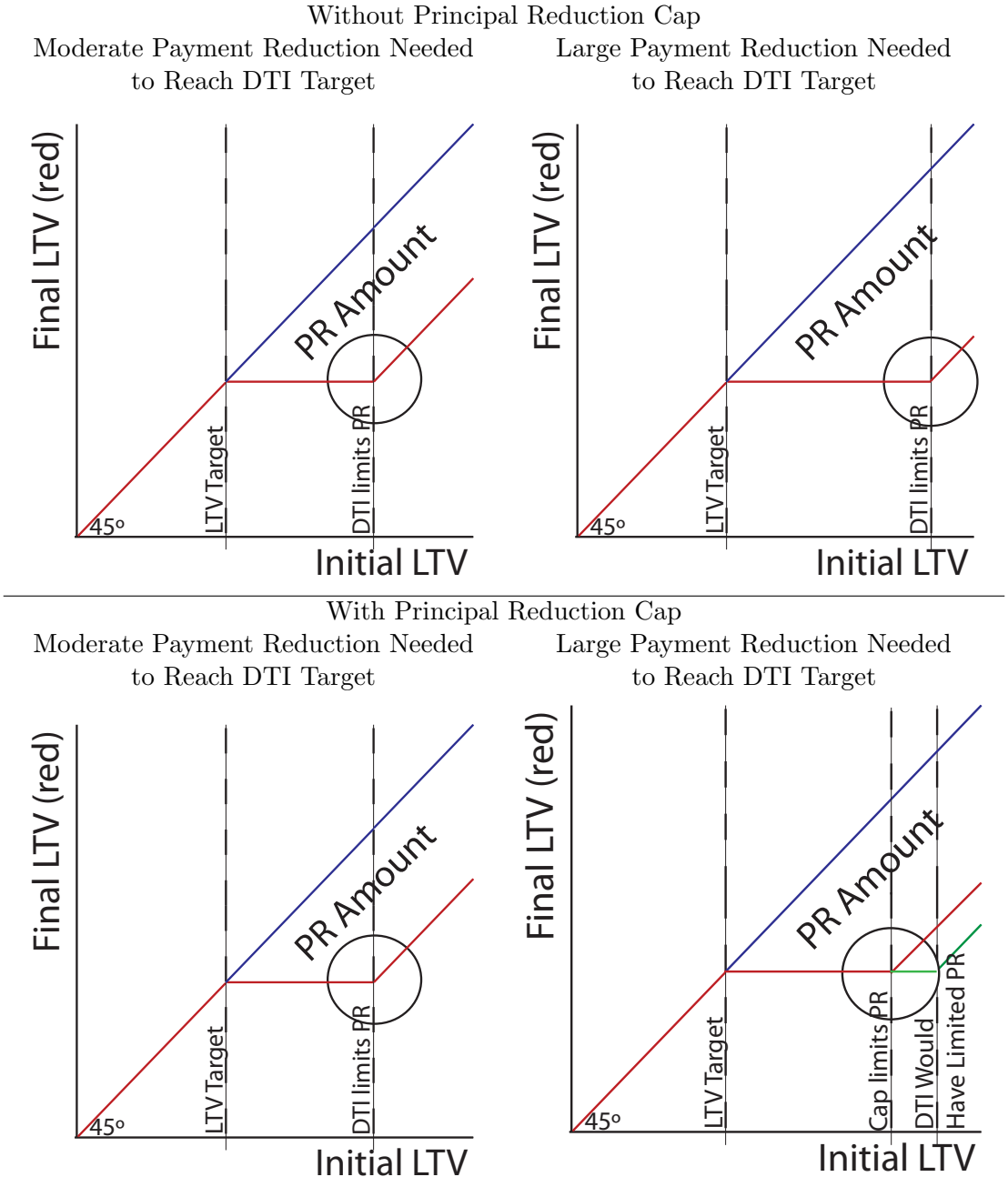
where k specifies the size of the neighborhood around the kink used in the analysis.

This kink is illustrated in Figure 1, which shows the relationship between LTV and the amount of principal reduction. The line in red plots the post-modification LTV as a function of the pre-modification LTV. The amount of principal reduction can be seen in the horizontal distance between this red line and the 45 degree line in blue. The figure on the left shows this relationship when a moderate payment reduction would be needed to achieve the DTI target; the figure on the right shows the case when a large payment reduction would be needed to achieve the DTI target. Below the circled threshold, increasing pre-modification LTV leads to increased principal reduction and does not increase post-modification LTV; above the circled threshold, increasing pre-modification LTV leads to increased post-modification LTV and does not change the mortgage modification. The location of that threshold varies with the payment reduction needed to meet the DTI target. The top panel shows the identification absent the 30% cap on principal reduction present for some servicers covering one-quarter of loans. The bottom panel shows the impact of the 30% cap. This cap is irrelevant for sufficiently low DTI or LTV; however, for high DTI modifications, the cap inhibits increasing initial LTV from increasing principal reduction.

The identification strategy is therefore to compare the relationship between default rates and pre-modification LTV on either side of the kink, controlling for the location of the kink.

The same idea can also be illustrated in Figure 2, which shows the amount of principal reduction (z-axis) as a function of LTV (x-axis) and affordability (z-axis, MDTI relative

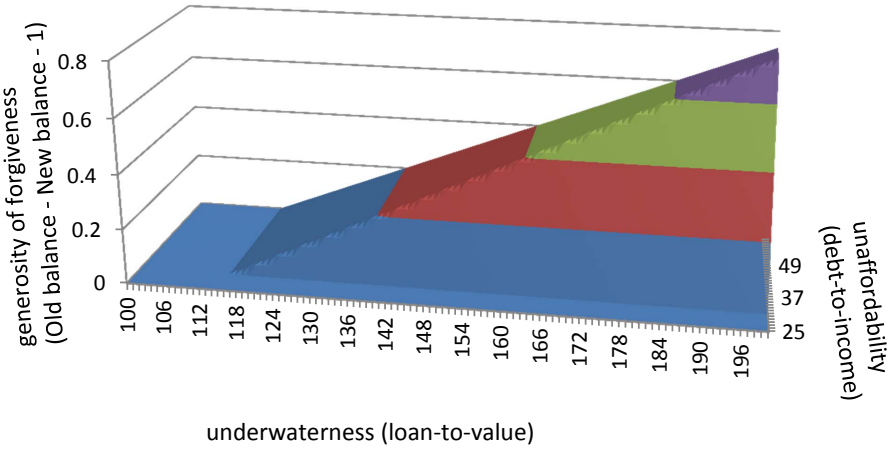
Figure 1: HAMP PRA Identification



See text for details.

to target).

Figure 2: Principal Reduction Amount



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.[13] We examine new permanent HAMP modifications on non-GSE loans (GSE loans are those guaranteed by Fannie Mae or Freddie Mac, which are ineligible for HAMP PRA) enrolled in 2011 and 2012.

HAMP PRA officially launched in October 2010, but borrowers must complete a 3-month trial period before becoming eligible for an "official" 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

[13]Not 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.

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 subject to this level of scrutiny, and are often 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 reduction on re-default in the first three months 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.[14] This is similar to the default measure used by Bhutta, Dokko, and Shan (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.[15] Because it takes 90 days to be dropped from HAMP due to delinquency, 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 first quarter of 2013. The first cohort of modifications (those that became permanent in the first quarter of 2011) have eight quarters of default data (from the second quarter of 2011 through the first quarter of 2013); the most recent cohort of modifications (those that became permanent in the fourth quarter of 2012) have only one quarter of default data (the first quarter of 2013).

[14]After being kicked out of 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 reduction 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.

[15]Default 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.

Table 2: Summary Statistics About Loans and Borrowers

	N	Median	Mean	St. Dev.	Min	Max
Balance pre-mod ($'000s$)	46,343	$289	$322	$173	$10	$1,279
Home value ($'000s$)	46,343	$175	$202	$116	$7	$856
Gross monthly income ($'000s$)	46,343	$4.4	$4.9	$2.4	$0.6	$22.2
Total Mortgage Payment ($'000s$)	46,343	$2.0	$2.2	$1.1	$0.3	$9.5
Principal & Interest Payment ($'000s$)	46,343	$1.6	$1.8	$0.9	$0.2	$9.0
FICO	43,423	556	563	68	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 reduction through the HAMP PRA program between January 1, 2011 and December 31, 2012. The sample excludes borrowers who received unsubsidized principal reduction (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.

We encounter extreme values in the data, some of which likely reflect data entry errors rather than true mortgage characteristics. On these grounds, we exclude borrowers with initial total DTI over 100% and initial LTV over 240%. 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 reduction through a program other than HAMP PRA. We drop one large servicer who uses a principal-reduction allocation method that does not generate the kink we exploit for identification; loans from this servicer are a majority of dropped loans. The dropped population comprised about 50% 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. During the enrollment period in our sample, 532,052 new permanent modifications were started in HAMP. Of these, 89,217 included HAMP PRA principal forgiveness amounting to $7.1 billion. Our sample consists of 46,343 loans, and $3.7 billion in principal forgiveness.

Figure 3: Loan Count Statistics

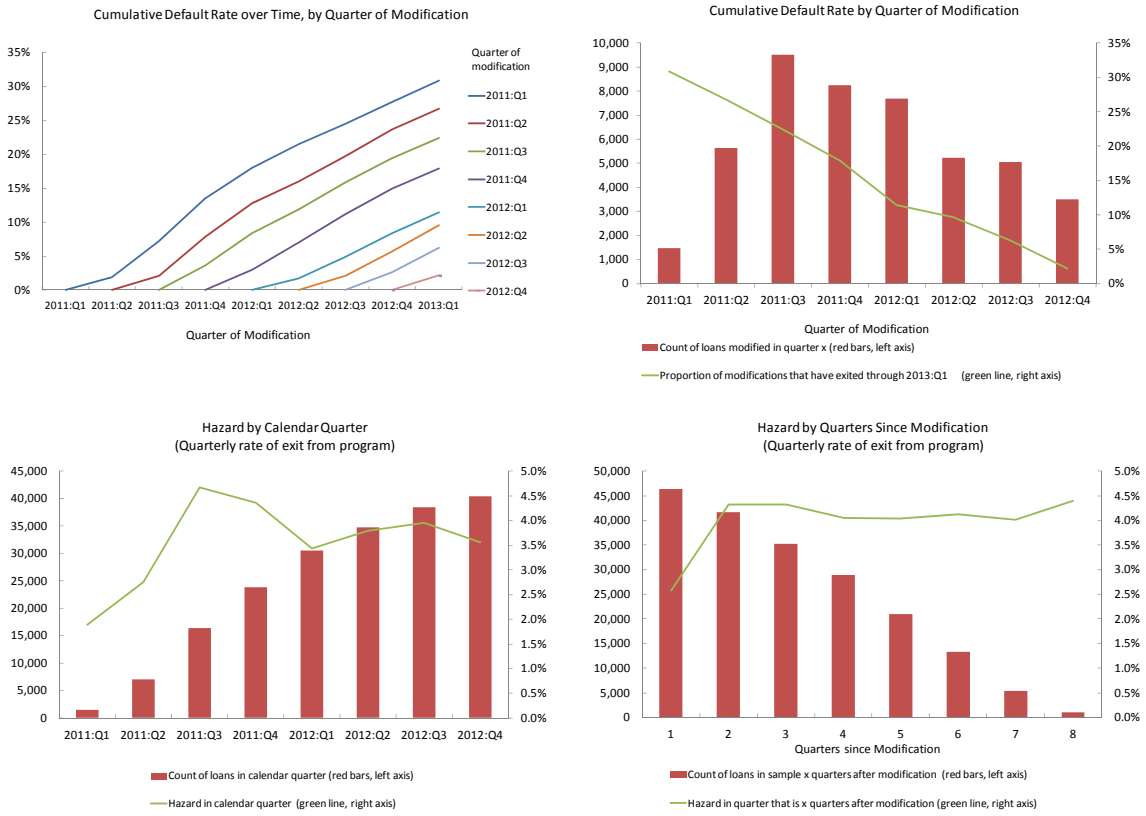
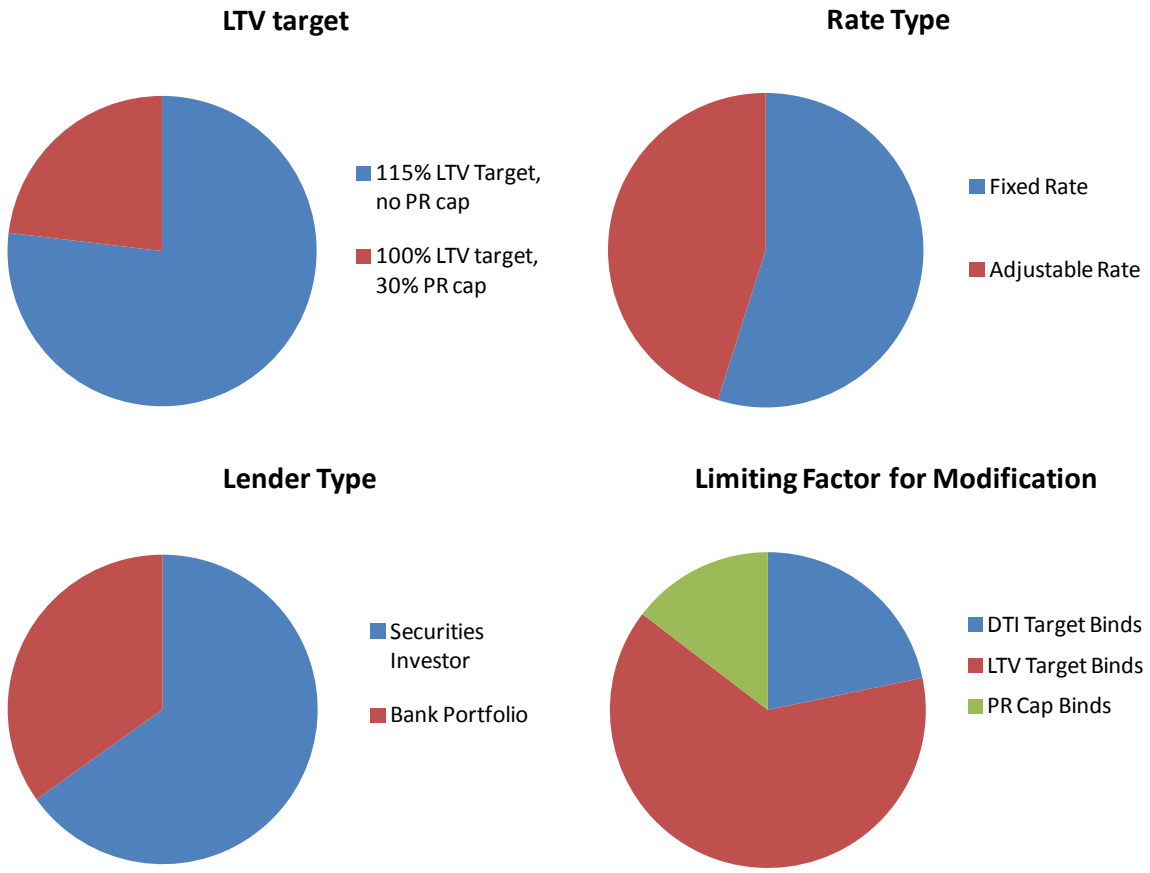


Figure 3 and 4 present information about counts, rates of HAMP exit following 90 days of delinquency, and sample attributes. Table 2 describes the borrowers and their loans before modification. Table 3 describes summary statistics about the modification terms.

Table 2 shows that the median home value in the sample is $\$175,000$ and the median pre-modification mortgage balance is $\$289,000$, though there is substantial variation. Table 3 shows that HAMP PRA reduces the median DTI from 44% to 31% and reduces median LTV from 160% to 115%, a 30% reduction in principal on average. Figures 3 (upper right corner) shows that the number of new modifications peaked in the third quarter of 2011 at just under $10,000$ for the quarter and has fallen consistently since then to below $4,000$ in the most recent quarter.

Figure 4 shows that roughly three-quarters of loans in the sample have servicers

Figure 4: Summary Statistics



with a 115% LTV target; none of these servicers have elected to place a cap on the total allowable amount of principal reduction; servicers for the remaining quarter of loans have a 100% LTV target; all of these servicers have elected to place a 30% cap on the principal reduction amount. Slightly more loans in the data have fixed rates than adjustable rates, and the majority of loans are held in mortgage backed securities and not held on bank balance sheets. In roughly two thirds of all cases, the LTV target is the limiting factor determining the amount of principal reduction received; reducing the mortgage balance until the LTV target is met is insufficient to reach the affordability target, and rate reduction (as well as possibly term extension and forbearance) are needed to reach the affordability target.

Figures 3 shows that default rates have been relatively constant as modifications age,

Table 3: Summary Statistics About Modification

	N	Median	Mean	St. Dev.	Min	Max
Total DTI pre-mod	46,343	44.3%	47.1%	12.3%	29.4%	100.0%
Total DTI post-mod	46,343	31.0%	31.0%	0.3%	19.8%	32.9%
Total payment reduction	46,343	29.9%	30.0%	16.1%	0.0%	69.0%
LTV before modification	46,343	159.8%	164.8%	33.6%	109.8%	240.0%
LTV after modification	46,343	115.0%	121.6%	16.8%	100.0%	237.7%
Principal balance reduction	46,343	29.7%	29.1%	16.7%	0.0%	73.5%
Rate pre-mod	46,343	6.5%	6.4%	2.0%	0.0%	15.1%
Rate post-mod	46,343	3.0%	3.9%	2.2%	1.0%	15.0%
Term pre-mod (months)	46,343	305	317	59	1	541
Term post-mod (months)	46,343	302	330	73	12	541

Mortgage debt-to-income (DTI) is the ratio of the mortgage payment (principal and interest) to gross income. Total DTI is the ratio of the total 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.

with a hazard of about 4% per quarter between the second and eighth 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 4.7% to 3.6% in the first quarter of 2013 – though the relationship is not monotonic.

Because the identification strategy relies on a kink in the principal reduction formula, it is critical that the amount of principal reduction received actually adhere to that formula. PRA participants receive almost exactly the amount of principal reduction predicted by the program. A regression to predict the natural log of actual principal reduction with the natural log of predicted principal reduction and no other covariates has a precisely-estimated coefficient of 1.007 and an R^2 of 0.98. While the analyses that follow examine the relationship between predicted principal reduction (given the program design outlined in Section 2) and default, results are nearly identical when actual principal reduction is used instead.

Table 4: Quarterly Hazard: Impact of Principal Reduction on Program Exit

Dep. Var.	Program exit, becoming 90+ days delinquent (quarterly)				
ln(predicted PR)	-0.350***	-0.247***	-0.284***	-0.271***	-0.306***
	(0.057)	(0.058)	(0.059)	(0.068)	(0.107)
ln(PR from LTV)	0.202***	0.145***	0.005	0.227***	-0.052
	(0.039)	(0.040)	(0.053)	(0.061)	(0.309)
ln(PR from DTI)	-0.429***	0.249***	0.141***	0.162***	0.630*
	(0.019)	(0.023)	(0.036)	(0.049)	(0.339)
			Controls		
LTV target = 115 percent?	YES	YES	YES	YES	YES
Quarters since mod	YES	YES	YES	YES	YES
Quarter of mod	NO	YES	YES	YES	YES
Total DTI pre-mod	NO	YES	YES	YES	YES
Interaction variable	NO	NO	YES	YES	YES
Other controls	NO	NO	NO	YES	YES
10-ppt LTV and DTI bins	NO	NO	NO	NO	YES
Observation Count	193,001	193,001	193,001	167,428	167,090
Loan Count	46,343	46,343	46,343	40,765	40,661
R^2	0.025	0.046	0.047	0.079	0.080

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. Since program exit is nearly impossible in the quarter in which a loan was modified, observations begin in the quarter following the quarter of modification. The regression shows results from a hazard for quarterly program exit, where the hazard is specified as a probit; coefficients are shown. "Quarter since modification controls" indicate dummy variables for the number of quarters since the modification; "quarter of modification controls" are dummy variables for the calendar quarter in which the loan was modified. Total DTI controls for the natural log of the pre-modification total debt-to-income (DTI) ratio. The interaction control is a control for the interaction of the natural logs of pre-modification total DTI and pre-modification loan-to-value (LTV). "Other Controls" includes FICO score, adjustable rate mortgage dummy, investor-owned mortgage dummy, ln income, ln pre-modification mortgage balance, length of trial modification (linear and squared), ln NPV of HAMP modification over no modification, ln 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.

4 Results

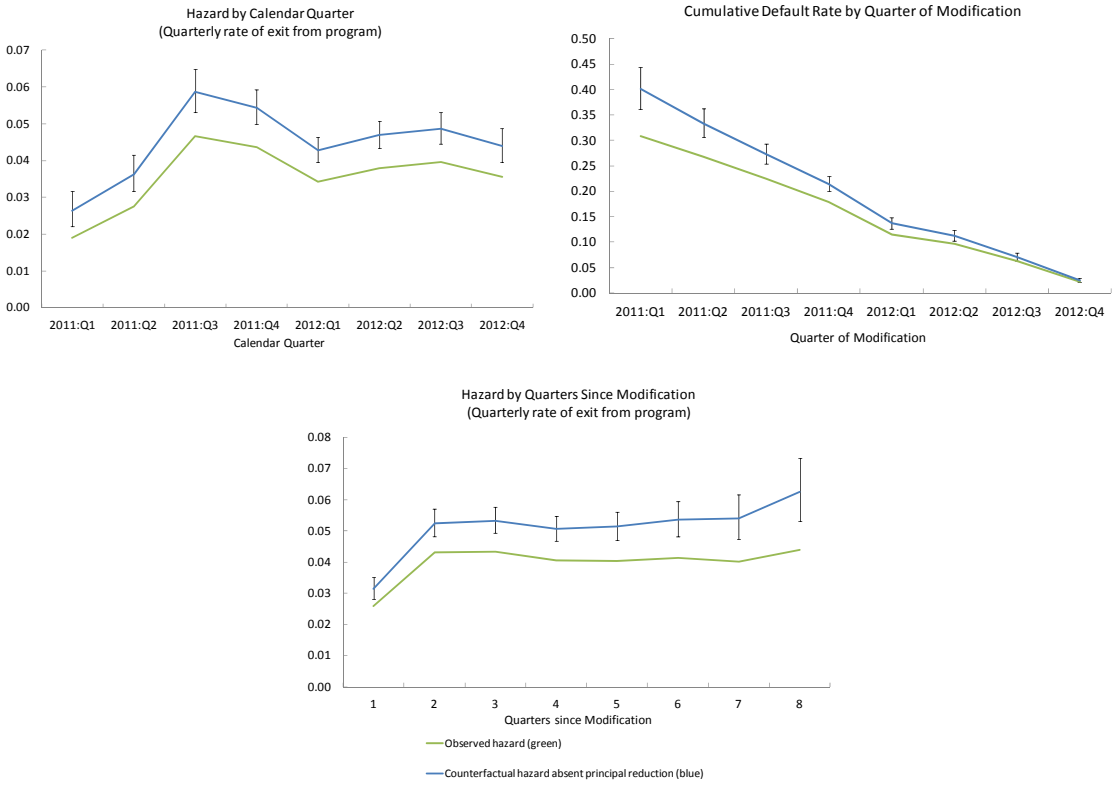
Table 4 shows the results of the probit regression in equation (7) to predict the quarterly default hazard using the natural log of the amount of principal reduction (PR, predicted by equations 1 and 5) and additional controls. The first column includes linear controls for the natural log of the principal reduction amount predicted by the borrower's LTV and the natural log of the PR amount predicted by DTI (which combined 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 8 dummy variables indicating the number of quarters since modification. The second column adds 8 dummy variables indicating the modification's cohort quarter, the borrower's and the borrower's pre-modification total DTI. The third column adds an interaction between the natural log of LTV and the natural log of DTI. The fourth column adds additional controls, including servicer dummies, state dummies, the borrower's FICO, NPV test results (for standard 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 PRA reduction predicted by LTV (in logs) and the PRA reduction predicted by DTI (in logs).

The coefficient on principal reduction varies between -0.25 and -0.35 and is statistically significant. On a baseline re-default hazard of 3.8%, a 10 percent principal reduction would reduce the re-default hazard by 0.2 to 0.3 percentage points (from 3.8% to 3.5% or 3.5%).

These results can be used to construct a counterfactual in which borrowers received no principal reduction, if the same level of payment reduction had been achieved through rate reduction, term extension, and forbearance.[16] Figure 5 illustrates the observed and

[16]The counterfactuals are estimated using the regression shown in the first column of Table 4 with additional controls for the quarter of modification (linear), and interactions between ln(predicted PR) and the number of quarters since modification and the quarter of modification. We calculate the counter-

Figure 5: Counterfactual: Estimated default rates absent principal reduction



The counterfactuals are estimated using the regression shown in the first column of Table 4 with additional controls for the quarter of modification (linear), an interaction between ln(predicted PR) and the number of quarters since modification, and an interaction between ln(predicted PR) and the calendar quarter of modification. This regression is also the last column in Table 6. We calculate the counterfactual hazard in each quarter in which that loan is present in the regressional sample; these are used to compute an average hazard among those observations that had survived to date. The error bars encompass the predicted default rates within two standard deviations of the point estimate.

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 reduction through HAMP PRA and the estimated cumulative default rate absent principal reduction. 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 4.7% (95% confidence interval (CI): 4.3% to 5.2%) – as compared to the 3.8% hazard observed in the data – had these borrowers not received principal reduction, which averaged 29.7% of the unpaid balance. The first cohort of PRA modifications in our sample (originated 2011:Q1) had a cumulative default rate of 31% during the 8 quarters of observed performance. We estimate that their default rate would have been 40% absent principal reduction (95% CI: 36% to 44%). The cumulative default rate in the sample (overall default rate thus far) is 15.8%; we estimate that it would have been 19.2% (95% CI: 17.8% to 20.9%) had these loans not received principal reduction. These results do not change when we cluster errors by loan identifier, clustering all quarters of data from the same loan.

4.1 Variation in Estimates

Table 5 shows that the results are robust to choice of sample, including ARM-only, FRM-only, private-investor-held, and portfolio-held. Table 6 allows the impact of principal reduction to vary with observables. We find no statistically significant variation in the default-reducing benefits of principal reduction by pre-modification LTV. However, principal reduction yields significantly larger reductions in default when pre-modification total DTI is lower.

factual hazard in each quarter in which that loan is present in the regressional sample; these are used to compute an average hazard among those observations that had survived to date. Note that this method yields a first-order approximation; had each successive hazard been realized, both the loan count and the composition would have been slightly different than the population used to generate the estimate.

Later cohorts show smaller default-reducing benefits of principal reduction than do early cohorts. (See last column of Table 6.) This finding is interesting because it leaves open the possibility that the composition of borrowers changed over the course of the program.[17] However, it is also possible that this result reflects a calendar time effect and not a cohort effect, with principal reduction becoming less effective in recent quarters. It is plausible that improvements in housing market conditions have lessened the default-reducing benefits of principal reduction.

There is no evidence that results derived using the two kinks yield different estimates. Table 7 breaks the sample into two subgroups based on the servicer's LTV target. Servicers with the lower LTV target of 100% also apply a cap to the PR amount granted. The last column of table 6 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 (without a statistically significant difference from one another), though the coefficient on the second kink is not statistically significantly different from zero due to its large standard error.

[17]Early in the sample, most underwater HAMP applicants could not have received HAMP PRA and should not have rationally expected to receive it; later in the sample, most underwater HAMP applicants *did* receive receive some form of principal reduction (either through HAMP PRA or through the attorney generals' mortgage settlement) and may have anticipated that they would receive it.

Table 5: Quarterly Hazard in Sub-Samples

Dep. Var.	Program exit, becoming 90+ days delinquent (quarterly)						
Sample	Full	ARM	FRM	PLS	Portfolio	LTV $\geq$ 180	LTV $\leq$ 180
ln(predicted PR)	-0.350***	-0.372***	-0.332***	-0.274***	-0.380***	-0.331***	-0.585***
	(0.057)	(0.088)	(0.079)	(0.071)	(0.109)	(0.108)	(0.095)
ln(PR from LTV)	0.202***	0.239***	0.184***	0.232***	0.097	0.283***	0.336***
	(0.039)	(0.058)	(0.055)	(0.045)	(0.081)	(0.088)	(0.118)
ln(PR from DTI)	-0.429***	-0.336***	-0.474***	-0.428***	-0.464***	-0.482***	-0.284***
	(0.019)	(0.028)	(0.029)	(0.022)	(0.038)	(0.024)	(0.036)
LTV target equal to 115?	YES	YES	YES	YES	YES	YES	YES
Quarters since mod	YES	YES	YES	YES	YES	YES	YES
Observations	193,001	88,660	104,341	120,786	72,120	129,754	63,247
Loan count	46,343	20,88825,455	30,177	16,166	31,263	15,080	
R^2	0.025	0.017	0.030	0.025	0.025	0.025	0.026

This table repeats the results from the first column of Table 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), porfolio 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).

Table 6: Variation in Impact of Principal Reduction

Dep. Var.	Program exit, becoming 90+ days delinquent (quarterly)						
Sample	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln(predicted PR)	-0.350***	-0.277**	-0.298**	0.308**	-0.278***	-0.511***	-0.496***
	(0.0574)	(0.134)	(0.116)	(0.144)	(0.0872)	(0.0933)	(0.144)
ln(predicted PR)^2		-0.119					
		(0.199)					
ln(predicted PR)			-0.0942				
x ln(initial LTV)			(0.184)				
ln(predicted PR)				0.683***			
x ln(initial TDTI)				(0.158)			
ln(predicted PR)					-0.0246		-0.00335
x quarters since mod					(0.0224)		(0.0249)
quarter of mod					-0.0205***	-0.0201**	
					(0.00748)	(0.00809)	
ln(predicted PR)					0.0525**	0.0510**	
x quarter of mod					(0.0231)	(0.0258)	
Observations	193,001	193,001	193,001	193,001	193,001	193,001	193,001
Loan count	46,343	46,343	46,343	46,343	46,343	46,343	46,343
R^2	0.0247	0.0247	0.0247	0.0370	0.0247	0.0248	0.0248

This table repeats the results from the first column of Table 4, allowing additional interaction effects.

Table 7: Separate Estimates from DTI-LTV and 30% Principal Reduction Cap Kink

Dep. Var.: Program exit, becoming 90+ days delinquent (quarterly)				
Sample	Full	LTV Target of Sample		
	Sample	115%	100%	100%
ln(predicted PR)	-0.350***	-0.248***	-0.383**	
	(0.057)	(0.079)	(0.158)	
ln(PR from LTV)	0.202***	0.117*	0.237***	0.271***
	(0.039)	(0.062)	(0.053)	(0.076)
ln(PR from DTI)	-0.429***	-0.467***	-0.387***	-0.371***
	(0.019)	(0.026)	(0.033)	(0.041)
ln(predicted PR uncapped)				-0.388**
				(0.158)
ln(predicted PR capped) −				-0.314
ln(predicted PR uncapped)				(0.194)
LTV target = 115%	YES	NO	NO	NO
Quarters since mod	YES	YES	YES	YES
Observations	193,001	137,253	55,748	55,748
Loan count	46,343	35,634	10,709	10,709
R^2	0.025	0.024	0.017	0.017

The first column of Table 7 repeats the baseline regression from the first column of Table 4. The second and third columns repeat this regression, decomposing the sample into loans with servicers with a 115% LTV target (and no cap on the amount of principal reduction allowed) and those with a 100% LTV target (and a 30% cap on the amount of principal reduction allowed). The final column replaces the ln (predicted PR) with ln (predicted PR uncapped) and ln (predicted PR capped) - ln(predicted PR capped). This final column provides two estimates for the impact of principal reduction on program exit for the 100% LTV target sample, one from the DTI-LTV kink (the coefficient from ln (predicted PR uncapped)) and one from the 30% cap kink (the coefficient from ln (capped PR) - ln(uncapped PR)).

4.2 Regression Kink Design

Table 8 repeats results from the first column of Table 4, with samples that sequentially (moving from left to right) zoom in closer around the indentifying kink in equation (3). Limiting the regression to observations near the kink implements a regression kink design (RKD) (Florens, Heckman, Meghir, and Vylacil, 2009; Card, Lee, Pei, and Weber, November 2012). Provided the region around the kink is small enough and assignment on either side of the kink is quasi-random, observable and unobservable variables should

Table 8: Quarterly Hazard: Impact of Principal Reduction Near Kink

Dep. Var.: Program exit, becoming 90+ days delinquent (quarterly)				
Sample	Full	Uncapped	Distance from Kink ≤ 0.5	Distance from Kink ≤ 0.25
ln(predicted PR)	-0.350***	-0.298***	-0.182*	-0.278
	(0.057)	(0.068)	(0.106)	(0.249)
ln(PR from LTV)	0.202***	0.172***	0.060	0.026
	(0.039)	(0.050)	(0.066)	(0.148)
ln(PR from DTI)	-0.429***	-0.469***	-0.565***	-0.469***
	(0.019)	(0.024)	(0.054)	(0.134)
LTV target = 115 percent?	YES	YES	YES	YES
Quarters since mod	YES	YES	YES	YES
Observations	193,001	156,701	106,374	62,464
Loan count	46,343	39,579	26,712	15,693
R^2	0.025	0.029	0.020	0.017

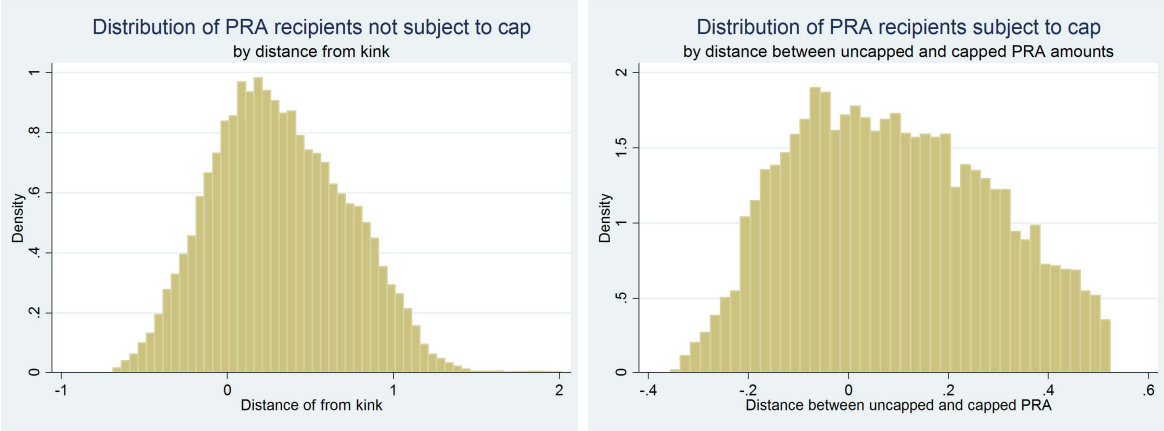
This table repeats results from the first column of Table 4, with the sample restricted to those observations sufficiently close to the kink from equation (3). The first column is identical to the first column from Table 4; the second column restricts the sample to observations not bound by the restriction that principal reduction not exceed 30% of the mortgage balance; the third column additionally restricts the sample to observations with log LTV within 0.5 (in logs) of the kink from equation (3); the final column restricts the sample to observations within 0.25 of the kink.

be the same for observations on either side of the kink. As a result, additional controls are unnecessary and concerns about omitted variables are lessened.

The first column includes the full sample; the second excludes loans that are bound by the principal-reduction cap (i.e., whose PR would be greater than 30% of their principal balance before modification, and whose servicers employ a cap). The third column includes uncapped loans within 50% of the kink ($k < 0.5$ in equation 8), and the fourth column includes uncapped loans within 25% of the kink; standard errors become extremely large for k substantially below 25%. Note that results are roughly unchanged when the regression is limited to the neighborhood around the indentifying kink; while standard errors grow as the neighborhood shrinks, point estimates change little.

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

Figure 6: Evidence on Bunching Around the Kink



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, Lee, Pei, and Weber, November 2012) Figure 6 shows that there is no evidence of "bunching" around the kink.

For 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.

5 Conclusion

The quarterly hazard - the proportion of loans that become more than 90 days delinquent and consequently exit the program - is 3.8% in our sample; we estimate it would have been 4.7% absent principal reduction, which averaged 29% of the initial mortgage balance. There is evidence that the benefits of principal reduction have fallen in later quarters,

possibly reflecting improvements in the housing market.

These results come with several caveats. First, the results may lack external validity or generalizability. The estimates here are for a sample of mostly-delinquent borrowers with mortgages deemed unaffordable based on DTI criteria, and who applied for a mortgage modification program. Principal reduction 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, Gerardi, and Willen (2008)) which suggests that the impact of negative equity on default decreases with affordability. Lastly, our counterfactual estimates measure the impact of principal reduction on default only for borrowers who participate in the program. They do not measure the impact of principal reduction in HAMP on borrowers' propensity apply to the program – either because they would have proceeded to foreclosure absent the potential for principal reduction, or because they became delinquent in order to receive principal reduction.

Third, HAMP PRA modifications are relatively new; as a result, re-default rates are available for at most two years from modification. The cost of providing principal reduction is lower when the lifetime default rate absent principal reduction is high. With only two years of post-modification data now available, that lifetime default rate is difficult to predict. The cumulative counterfactual default hazard among principal-recipients has exceeded 40% after two years among borrowers whose HAMP PRA modifications became permanent in the first quarter of 2011, and the quarterly hazard has not dropped substantially over time. This suggests that the lifetime default rate might be quite high. However, without estimates of the lifetime default rate, the recovery rate in the event of default, the externalities associated with default, and the importance of moral hazard –

the proportion of people who would not have gone delinquent absent a principal reduction program but who become delinquent in order to qualify for principal reduction – the social and private benefits of principal reduction cannot be precisely estimated. This paper aims to cleanly estimate one key input into such a calculation: the default-reducing benefits of principal reduction.

There is reason to believe that the default-reducing benefit to principal reduction 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 reduction recipients will be better positioned to weather those payment shocks. On the other hand, we might expect the impact of principal reduction to decline as both recipients and non-recipients regain their equity positions. These questions remain topics of future observation and analysis.

References

Agarwal, S., G. Amromin, I. Ben-David, S. Chomsisengphet, and D. Evanoff (2011): "Market-Based Loss Mitigation Practices for Troubled Mortgages Following the Financial Crisis," FRB of Chicago Workingpaper No. 2011-03.

Bajari, P., S. Chu, and M. Park (2010): "An Empirical Model of Subprime Mortgage Default from 2000-2007," Working Paper.

Bhutta, N., J. Dokko, and H. Shan (2010): "The Depth of Negative Equity and Mortgage Default Decisions," Federal Reserve Board of Governors Working Paper.

Boyce, A., G. Hubbard, C. Mayer, and J. Witkin (2012): "Streamlined Refinancings for up to 14 Million Borrowers," Columbia University GSB Working Paper.

Card, D., D. S. Lee, Z. Pei, and A. Weber (November 2012): "Nonlinear Policy Rules and the Identification and Estimation of Causal Effects in a Generalized Regression Kink Design," NBER Working Paper 18564.

Corelogic, I. (March 2013): "CoreLogic Negative Equity Report Q4 2012," .

Das, S. (2012): "The Principal Principle," *Journal of Financial and Quantitative Analysis*, 47(6), 1215–1246.

Deng, Y., J. M. Quigley, and R. van Order (2000): "Mortgage Termination, Heterogeneity, and the Exercise of Mortgage Options," *Econometrica*, 68(2), 275–307.

Dynan, K. E. (Spring 2012): "Is Household Debt Holding Back Consumption?," *Brookings Papers on Economic Activity*, pp. 299–362.

Ferreira, F., J. Gyourko, and J. Tracy (2010): "Housing Busts and Household Mobility," *Journal of Urban Economics*, 68(1), 34–45.

——— (2013): "Housing Busts and Household Mobility: an Update," *Economic Policy Review*.

Florens, J., J. J. Heckman, C. Meghir, and E. Vylacil (2009): "Identification of Treatment Effects Using Control Functions in Models with Continuous Endegnous Treatment and Heterogeneous Effects," *Econometrica*, 76, 1191–1206.

Foote, C., K. Gerardi, and P. S. Willen (2008): "Negative Equity and Foreclosure: Theory and Evidence," *Journal of Urban Economics*, 64(2), 234–245.

Fuster, A., and P. S. Willen (2012): "Payment Size, Negative Equity, and Mortgage Default," New York Federal Reserve Staff Report No. 582.

Ghent, A., and M. Kudlyak (2011): "Recourse and Residential Mortgage Default: Evidence from US States," *The Review of Financial Studies*, 24(9), 3139–3186.

Hahn, J., P. Todd, and W. Van der Klaauw (2001): "Identification and Estimation of Treatment Effects with a Regression-Discontinuity Design," *Econometrica*, 69(1), 201–209.

Haughwout, A., D. Lee, J. Tracy, and W. van der Klaauw (September 2011): "Real Estate Investors, the Leverage Cycle, and the Housing Market Crisis," Federal Reserve Bank of New York Staff Report no. 514.

Haughwout, A., E. Okah, and J. Tracy (2010): "Second Chances: Subprime Mortgage Modification and Re-Default," Federal Reserve Bank of New York Staff Reports, number 417.

Jiang, W., A. Nelson, and E. Vytlacil (2011): "Liar's Loan? Effects of Origination Channel and Information Falsification on Mortgage Loan Delinquency," Columbia University Working Paper.

Keys, B., T. Mukherjee, A. Seru, and V. Vig (2010): "Did Securitization Lead to Lax Screening? Evidence from Subprime Loans," .

Lee, D., and T. Lemieux (2010): "Regression Discontinuity Designs in Economics," *Journal of Economic Literature*, 48(2), 281–355.

Mian, A., and A. Sufi (2011): "House Prices, Home Equity-Based Borrowing, and the U.S. Household Leverage Crisis," *American Economic Review*, 101, 2132–2156.

Schulhofer-Wohl, S. (2012): "Negative Equity Does Not Reduce Homeowners Mobility," *Quarterly Review*, 3511.
Mortgage Bankers Association

Mortgage Bankers Association (May 2013): "National Delinquency Survey," .

Tracy, J., and J. Wright (2012): "Payment Changes and Default Risk: The Impact of Refinancing on Expected Credit Losses," Federal Reserve Bank of New York Staff Report No. 562.