B  Effect of Payment Reduction on Default

In this section we analyze the effect of payment reduction on borrower default. Using a regression discontinuity empirical strategy, we find that immediate payment reduction with no change in long-term obligations significantly reduces default. Our findings indicate that additional payment reduction is effective irrespective of a borrower’s payment-to-income ratio, which is contrary to the view of affordability that has defined government housing policy since 1937. Furthermore, our findings suggest that the arbitrary income-ratio target embodied in the government program crowded out private bilateral modifications that could have been more generous, and led to fewer defaults, for up to 40% of HAMP borrowers. Finally, we show that by extending mortgage maturities, modifications can be structured so as to reduce defaults in a way that is likely to leave borrowers, investors, and taxpayers better off.

B.1  Variation in Payment Reduction Between HAMP and Chase Modifications

We analyze the effect of immediate payment reduction by comparing borrowers with HAMP modifications to those with proprietary modifications offered by Chase. Although servicers were required to offer all eligible borrowers HAMP modifications, HAMP had strict eligibility rules as described in section 2.1. Borrowers ineligible for HAMP were often eligible for alternative proprietary modification programs offered by their servicer. We focus in particular on proprietary modifications offered by Chase. This section discusses two important features of the Chase modification program which allow us to carefully study the effect of modifications that reduce immediate payments without reducing long-term obligations, while the next section describes the specific HAMP eligibility rule we rely on in our empirical strategy.

The design of HAMP and the Chase modification program reflect different views about the most effective way to reduce defaults. HAMP was designed with an explicit 31% payment-to-income (PTI) ratio target. This income ratio target evolved from the National Housing Act of 1937, which established a PTI limit in the federal government’s public housing program (Schwartz and Wilson 2008). Over the subsequent 80 years, the target spread throughout federal housing policies, first in the rental market, then in the owner-occupied market, and finally in the design of mortgage modifications during the Great Recession. Adopting this income ratio target in a modification program assumes that borrowers with high PTI ratios must need much larger payment reductions in order to avoid default than borrowers with lower PTI ratios, and that borrowers with PTI ratios below 31% already have “affordable” mortgages and hence do not need assistance to avoid default.

The first important feature of the Chase modification program is that, in contrast to the rigid income ratio target in HAMP, Chase joined a wide range of servicers and investors in the housing market (including Fannie Mae and Freddie Mac) in pursuing a strategy which added a payment-reduction target. Under this alternative view, the amount of payment reduction relative to the status quo is at least as important for reducing defaults as ensuring that the new payment is

\footnote{51 For more detail about the evolution of different modification strategies, see Cowley (2017).}
an “affordable” share of income according to the government’s metric. Reflecting this view, the
Chase program mimics HAMP in modifying loans such that new payments hit the 31% PTI target,
but adds the stipulation that if this results in a payment reduction of less than 30%, that the
modification instead targets a 30% payment reduction.\textsuperscript{52} Under this rule, Chase modifications
result in immediate payment reductions that are at least as great as in HAMP, and greater for
borrowers with low PTI ratios who are either ineligible for HAMP or receive less than 30% payment
reductions in HAMP.

The second important feature of the Chase modification program is that maturity extension
was used as a low-cost tool for achieving deeper immediate payment reductions without reducing
long-term obligations. A range of contract terms can be modified in order to achieve a given amount
of immediate payment reduction. As described in section 2.1, HAMP reduced payments by first
providing interest rate reductions, then maturity extensions, and finally principal forbearance as
necessary to achieve the 31% PTI ratio target. In contrast, Chase modifications targeted larger
payment reductions by first extending maturity and amortization terms (which we call maturity ex-
tension for simplicity).\textsuperscript{53} In this way deeper immediate payment reductions are offset by continued
payments in the long-term. The structure of Chase modifications can be seen visually in Appendix
Figure B.3, which shows the average path of payments owed before and after modification.\textsuperscript{54} Low
payments are sustained throughout the early mortgage term (since few borrowers have interest
rates re-setting from temporary reductions), and continue for up to 40 years (since many borrowers
have extended maturities). We compare cash-flows for various modification groups in more detail
in section B.3.

B.2 31% Payment-to-Income Regression Discontinuity Empirical Strategy

Our strategy to identify the effect of immediate payment reduction on default uses variation
generated by HAMP’s 31% PTI eligibility cutoff and the different payment reduction targets used
in HAMP and the Chase modification program. Since HAMP was designed to reduce monthly
payments to 31% of a borrower’s income, borrowers whose PTI ratio was already below 31% were
ineligible for HAMP. These borrowers were only evaluated for Chase’s proprietary modification
program.

\textsuperscript{52}The Chase program specifically targets a 25% reduction in principal, interest, taxes, and insurance (PITI) pay-
ments, which translates to a 30% principal and interest reduction for most borrowers. We follow the convention in
the prior literature and characterize the reductions relative to prior principal and interest payments.

\textsuperscript{53}Our language follows prior work by Argyle et al. (2017) who discuss maturity choices in the auto loan market
in a context where amortization and maturity terms are equivalent. In both HAMP and the Chase modification
program servicers extended mortgage maturities and re-amortized the mortgage to the new term, unless either step
was prohibited by investor agreements (in which case only the permitted step, if any, was pursued). In theoretical work
analyzing consumer debt restructuring policies Clara and Cocco (2016) use “maturity extension” to mean something
different. They consider a modification with interest-only payments for a number of periods, with a corresponding
increase in loan maturity and no change in the amortization schedule during the periods when principal payments
are made.

\textsuperscript{54}While the HAMP program ended in December 2016, the Chase modification program described in this section
is ongoing and its rules are subject to change. Our description of the program reflects guidelines in place during our
analysis period.
The difference in modification program rules generates substantial variation in the amount of immediate payment reduction received by borrowers on either side of HAMP’s 31% PTI eligibility cutoff. Above the cutoff borrowers receive a mix of HAMP modifications with small payment reductions (since these borrowers are already close to HAMP’s 31% PTI target) and Chase modifications with large payment reductions (since Chase had a minimum 30% payment reduction target). Below the cutoff, all borrowers receive Chase modifications with large payment reductions. The result is that the average payment reduction jumps sharply at the cutoff.

Employing a fuzzy regression discontinuity strategy, the treatment effect of receiving payment reduction is determined by the jump in default divided by the jump in the amount of payment reduction received at the cutoff. Similar to equation 2, let $Y$ be the outcome variable of interest, and let $\Delta \text{Pay}$ be the percent change in mortgage payment from the modification. The estimand for the effect of a 1% payment reduction is given by

$$
\tau = \frac{\lim_{\text{PTI} \downarrow 31\%} E[Y|\text{PTI}] - \lim_{\text{PTI} \uparrow 31\%} E[Y|\text{PTI}]}{\lim_{\text{PTI} \downarrow 31\%} E[\Delta \text{Pay}|\text{PTI}] - \lim_{\text{PTI} \uparrow 31\%} E[\Delta \text{Pay}|\text{PTI}]}.
$$

(7)

We follow the procedures described in section 4.2 to estimate $\hat{\tau}$ using borrowers in the JPMCI bank dataset. The full sample includes all non-GSE borrowers who received a modification through either the HAMP or Chase programs. We further limit the sample to modifications performed in the fourth quarter of 2011 or later, and who are observed at least two years after modification. The Chase proprietary program we study was instituted after HAMP was in place, and by the fourth quarter of 2011 it was sufficiently established such that any borrower ineligible for HAMP due to the PTI cutoff could plausibly receive a Chase modification.\textsuperscript{55} The sample includes borrowers with PTI ratios between 25 and 80.\textsuperscript{56} For symmetry around the 31% PTI cutoff, most figures in the following sections plot data for borrowers with PTI ratios between 25% and 37%. The optimal bandwidth according to the Imbens and Kalyanaraman (2012) procedure is 4.5 percentage points of PTI, though we report estimates for multiple bandwidths.

### B.3 Internal Validity of Design

As with the investor NPV regression discontinuity strategy, the validity of this research design rests on two assumptions. First, there is a discontinuous jump in the amount of immediate payment reduction received at the cutoff. Second, all other variables that could affect outcomes are continuous at the cutoff.

The top panel of Figure B.1 validates the first assumption. It shows that borrowers below the cutoff receive payment reductions that are 17.4 percentage points more generous than those received by borrowers above the cutoff.\textsuperscript{57} The figure also shows that payment reductions are approximately

\textsuperscript{55} Chase had a variety of other modification programs with different designs that preceded HAMP.

\textsuperscript{56} Borrower density thins above PTI ratios of 80, and borrowers with PTI ratios below 25 are evaluated according to different program rules.

\textsuperscript{57} This figure, and all subsequent figures in the section, remove the 275 observations with PTI ratios between 31% and 31.1%. Borrowers this close to the cutoff receive an amount of payment reduction which is about halfway between that received by borrowers clearly above and clearly below the cutoff. This can be seen in the top panel of Appendix
constant below the cutoff, consistent with the payment reduction target discussion above, and that payment reductions are increasing in PTI above the cutoff, consistent with the PTI ratio target discussion above. Above the cutoff, about half of borrowers receive deep payment reductions similar to households below the cutoff, while the other half face a 31% PTI ratio target and therefore receive virtually no payment reduction. Although borrowers above the cutoff who receive HAMP modifications with a 31% PTI ratio target would have received larger payment reductions in the Chase program, HAMP rules prohibited servicers from offering private sector alternatives to any HAMP-eligible borrower, under the assumption that private modifications wouldn’t be as effective as those subsidized by the government.\textsuperscript{58} Thus the only borrowers above the cutoff receiving Chase modifications are those failing to meet one of the other eligibility criteria described in section 2.1.\textsuperscript{59}

Our estimate is a local average treatment effect for the borrowers moved from HAMP to Chase modifications due to the 31% PTI cutoff.

Figure B.2 shows that the treatment we study is an immediate payment reduction with no reduction in long-term payments. Because much of the additional payment reduction received by borrowers below the cutoff is achieved via maturity extension, deeper immediate payment reductions are offset by continued payments further out in the mortgage term, such that the total NPV of the cash-flows owed under the mortgage contract is similar for borrowers just above and just below the cutoff. The top panel shows that payments for borrowers just below the cutoff are lower for the first 22 years, before rising relative to those of borrowers just above the cutoff. The bottom panel summarizes the financial impacts of the modifications for these two groups,\textsuperscript{60} and reports that the NPV of the mortgage payments owed under the new mortgage contract is nearly identical for borrowers just above and just below the cutoff.\textsuperscript{61} Figure B.2 also shows that borrowers below the cutoff receive less generous principal reductions than those above the cutoff. This is because these borrowers are ineligible for the subsidized principal reduction in HAMP. Hence borrowers below the cutoff receive a relative reduction in immediate mortgage payments with a relative increase in mortgage principal, with no change in the NPV of payments owed under the full contract. Because the NPV of long-term payments is unchanged, and we found no independent impact of principal reductions on default in section 4.4, we will attribute the causal impact of this treatment on default

Figure B.4. The bottom panel of this figure shows that the estimated effect of payment reduction on default is nearly identical when these borrowers are included.

\textsuperscript{58}Although the government prevented servicers from offering private alternatives to HAMP-eligible borrowers, servicers could offer deeper payment reductions within HAMP. However they could only do so if they followed the priority of modification steps allowed within HAMP (i.e. servicers couldn’t reduce payments of HAMP borrowers below 31% PTI by offering more maturity extension until they had reduced the interest rate all the way to 2%, which is more costly to the investor).

\textsuperscript{59}We do not observe the full set of eligibility criteria in our data and include all borrowers who received either modification type.

\textsuperscript{60}Appendix Figure B.5 reports the RD estimates for the jump in principal reduction and the NPV of payments owed at the cutoff.

\textsuperscript{61}This NPV calculation only reflects the amount owed under the mortgage contract, and does not reflect any behavioral response such as different default probabilities or prepayment behavior. It uses a 4.1% discount rate, equal to the average market mortgage interest rate over the program period, which is the rate used to discount cash flows in the government-mandated model described in Section 2.2. A higher discount rate would lead to larger savings for borrowers below the cutoff relative to those above the cutoff, since savings were front-loaded for these borrowers.
to the immediate payment reduction portion of the treatment. In the next section we provide a bound on our estimate of the effect of payment reduction under the alternative assumption that the principal increase actually had an offsetting effect.

Appendix Figure B.6 provides evidence supporting the second assumption. The first four panels show the LTV ratio, months past due, borrower monthly income, and pre-modification monthly payment around the cutoff. In all cases these loan and borrower characteristics trend smoothly. In the bottom panel we use these observable borrower characteristics to predict default, and show that predicted default is also smooth at the cutoff. Finally, Appendix Figure B.7 shows that borrower density is also smooth around the cutoff.

### B.4 Results: Effect of Payment Reduction on Default

We find that immediate payment reduction significantly reduces default rates. The bottom panel of Figure B.1 shows the reduced form of the fuzzy regression discontinuity specification, plotting the default rate on the y-axis. The figure provides visual evidence that payment reduction reduces default in two ways. First, the default rate falls sharply by 4.7 percentage points at the 31% PTI cutoff. Second, the slope of the estimated default rates in the bottom panel mirrors the slope of the payment reductions in the top panel; default rates are approximately constant on the left-hand side of the cutoff, consistent with a constant amount of payment reduction, and are falling on the right-hand side of the cutoff, consistent with a rising amount of payment reduction (this pattern is even more striking in Appendix Figure B.4, which plots the first stage and reduced form for borrowers with PTI ratios all the way out to 50%).

Our point estimate of $\hat{\tau}$ from equation 7 is that an extra 1% payment reduction reduces default rates in the two years after modification by 0.27 percentage points, or by 0.95% of the mean above the cutoff. Appendix Figure 4 tests the sensitivity of our results to the bandwidth chosen for the local linear regression. Our central estimates are constructed using the optimal bandwidth from the Imbens and Kalyanaraman (2012) procedure, which is 4.5 points of PTI. We test alternative bandwidths between 1 and 10 and find that the point estimate is stable. Furthermore, our point estimate is similar (rising to 1.2%) if we use the upper bound of our 95% confidence interval from section 4.4 to adjust from any potential effect of the relative increase in mortgage principal at the cutoff.63

Our results suggest that immediate liquidity provision is the key driver of the default reductions

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62 Unlike in the matched HAMP credit bureau dataset used for the investor NPV strategy, borrower credit score is not available in the JPMCI bank dataset.

63 If we take the upper bound of our 95% confidence interval for the impact of principal reduction on default from section 4.4, and scale it by the amount of relative principal increase received by borrowers just below the 31% PTI cutoff, we find that a principal increase of this magnitude would have led to at most a 1.2 percentage point increase in default rates. If the payment reductions had to offset this effect, this would mean that the reduced form jump in default at the cutoff would have been 5.9 percentage points without the principal increase rather than 4.7 percentage points, or alternatively that each 1% reduction in payment reduced default rates by 0.34 percentage points (1.2%), similar to our baseline estimate of 0.27 percentage points (0.95%).
found in prior work analyzing the effect of sustained payment reductions. To our knowledge, this is the first estimate of the effect of an immediate payment reduction with no reduction in long-term payments. Our results are similar to two types of estimates in the prior literature which analyzes sustained payment reductions. First, Agarwal et al. (2011) and Haughwout et al. (2016) analyze modifications provided to delinquent borrowers before the implementation of the HAMP program. They find that a 1% immediate payment reduction that also reduces long-term debt obligations is associated with a 1.1% to 1.3% reduction in default rates. Second, other authors have analyzed the effect of sustained payment reductions for non-distressed borrowers. Although differences in borrower characteristics and baseline default rates make it difficult to directly compare magnitudes between distressed and non-distressed borrowers, this literature has found that a 1% payment reduction is associated with a 1.1% to 2.75% reduction in default rates. The similarity between our estimates of the effect of immediate payment reduction and those of the prior literature analyzing the effect of sustained payment reductions suggests that immediate liquidity provision is a main driver of the default reductions documented in previous work.

### B.5 Implications

Our finding that the type of payment reduction we study can substantially reduce defaults has three broader implications. This section discusses each implication in turn.

First, our findings reject the homogeneous-preferences view of housing affordability that has been embodied in government housing policy since 1937. A one-size-fits-all PTI ratio target could be justified by a model where agents have Cobb-Douglas preferences over housing and non-housing consumption and all have identical tastes for housing. Such a model predicts that all households will choose to spend the same share of their income on housing. Payments above this share would lead to defaults while payments below this share would be sustainable. With a 31% PTI target, this view implies that default rates should be converging to zero as average PTI approaches 31%. In contrast, we show that default rates are well above zero for households below this cutoff.

Instead, our results are more consistent with a model with heterogeneous tastes for housing where liquidity shocks are the main drivers of default. A model with heterogeneous preferences for

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64 In addition, Agarwal et al. (2016a) show that HAMP modifications with both short and long-term payment reduction led to significant reductions in default rates, though they do not estimate an elasticity with respect to a given quantity of payment reduction.

65 See Ehrlich and Perry (2015), Tracy and Wright (2012), Fuster and Willen (2017), and DiMaggio et al. (2017). The latter three of these papers analyze the effect of payment reductions caused by downward adjustments of interest rates for borrowers with adjustable rate mortgages. As Fuster and Willen (2017) discuss, to the extent that borrowers are aware of their mortgage terms and follow the movement of underlying index rates, these estimates may already be capturing only the liquidity effects of lower payments since borrowers would already have been anticipating and responding to the long-term payment reductions. Similarly, in contemporaneous work Scharlemann and Shore (2017) analyze the effect of sustained payment increases for non-distressed borrowers in a setting where these payment increases are pre-determined five years ahead of time (resulting from a step up in interest rates as part of a previous mortgage modification). They find that a 1% increase in payments is associated with a 0.8% reduction in default rates.

66 An alternative justification specific to the owner-occupied market is the value of PTI limits from a macroprudential policy perspective. Greenwald (2017) finds that a cap on PTI ratios is more effective than a cap on LTV ratios at limiting boom-bust cycles.
housing would suggest that different households have different preferred income shares of housing. Households could support a wide range of potential PTI ratios, but temporary income or expense shocks would induce them to default even at potentially low PTI ratios. In these cases, a payment reduction would plausibly allow them to maintain payments. Our empirical results are consistent both with liquidity-shock driven defaults (section 4.6) and the effectiveness of payment reductions even for low-PTI borrowers. We find that payment reductions led to a substantial reduction in default rates, even for borrowers already at the 31% PTI ratio target who supposedly had “affordable” mortgages according to the government’s rule. Furthermore, for borrowers above the 31% cutoff, those who started with higher PTI ratios and thus received more payment reduction had lower default rates than those starting with lower PTI ratios, even though HAMP reduced the PTI ratio of both groups to the same 31% target.

Second, our data showing that the government’s rigid income ratio target generated less generous modifications than private sector alternatives, coupled with the government’s requirement that borrowers be offered HAMP before private alternatives, raise concerns about substantial crowd-out which may have had the unintended effect of increasing defaults for up to 40% of HAMP borrowers. The 31% PTI target in HAMP means that borrowers with pre-modification PTI ratios below 41.5% received payment reductions of less than 30%. For these borrowers, an alternative private bilateral modification program such as the one we studied would have resulted in more generous immediate payment reduction and, according to our empirical results, lower default rates without requiring any government intervention or subsidy. About 40% of all borrowers with HAMP modifications (625,000 borrowers) were in this region, and the government spent approximately $7 billion subsidizing potentially less effective modifications for these borrowers. Furthermore, the government explicitly prohibited servicers from offering alternative private modifications to any HAMP-eligible borrower under the assumption that the private modifications wouldn’t be as generous or effective as those subsidized by the government. Our data on proprietary modifications and the HAMP-first requirement indicate that HAMP crowded out private modifications that could have been more effective for a large fraction of borrowers in the government program.

Third, our results imply that since the amount of immediate payment reduction appears more important than the way that payment reduction is achieved, maturity extension can be used to reduce short-term defaults in a way that is likely to leave borrowers, investors, and taxpayers better off. To understand why this is true, it is useful to revisit the particular structure of mortgage

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67 This figure includes subsidies paid to investors, servicers, and borrowers. See Treasury Department (2014c) for a detailed breakdown of these subsidies.

68 While our emphasis is on crowd-out on the intensive margin of the quality of modifications, Agarwal et al. (2016a) provide evidence on the extensive margin in terms of the quantity of modifications. They show that each HAMP modification is associated with about 0.84 more “net” modifications, suggesting that the program did not substantially reduce the total number of private modifications that would have been offered in the absence of the program. They argue that by inducing more borrowers to apply for modifications, HAMP increased the private modification rate of HAMP-ineligible borrowers, offsetting the reduced private modification rate of HAMP-eligible borrowers. Our evidence suggests that at least some of the borrowers pushed from private to HAMP modifications would have received larger payment reductions, and had lower short-term default rates, if they had remained in private modifications designed to emphasize payment reduction rather than an income-ratio target.
modifications around the cutoff we study. Because Chase modifications achieved larger payment reductions primarily by extending mortgage maturities, relative to borrowers above the 31% PTI treatment discontinuity, those below the cutoff traded more generous immediate payment reduction for continued payments in the long-term. A maturity extension with no other changes to the mortgage contract is equivalent to the investor “lending” the borrower their monthly payment reductions at the mortgage interest rate, with repayments on this “new” loan beginning at the end of the original mortgage term and continuing through the end of the new loan term.

This particular form of loan restructuring is likely to leave borrowers, investors, and taxpayers better off. For borrowers, a maturity extension which moves their funds from the future to the present might be particularly valuable in periods of acute economic distress. In the short term, lower default rates indicate that more borrowers will remain in this contract, which by revealed preference indicates that they found it more attractive than the contract with less generous payment reductions. Borrowers may also be better off in the long-term because payments are still lower on average 22 years after modification, by which point point borrowers will likely have regained positive home equity.\(^69\) It is thus likely that foreclosures are permanently lower under this modification type. Investors will also be better off as long as the reduction in default rates offsets any increase in prepayment risk and any potential reduction in the net present value of the cash-flows owed on the mortgage contract.\(^70\) Finally, the government spent substantial resources subsidizing HAMP modifications above the 31% PTI cutoff with small payment reductions and high default rates, whereas borrowers below the cutoff received proprietary modifications requiring no government assistance which had large payment reductions and low default rates.

Our findings that payment reductions can be structured so as to reduce default rates while leaving all parties better off contrast sharply with our findings for principal reduction, which was ineffective even while being costly to both investors and taxpayers. Future private and public modification programs will have a menu of options for restructuring loans. Our findings suggest that among these options, those that maximize immediate payment reduction are likely to be most effective, and that maturity extension is a particular way to achieve large immediate payment reductions at little cost to investors and taxpayers.

Our empirical results about ex-post debt restructuring help inform the theoretical debate about optimal ex-ante mortgage design. A number of recent papers have analyzed alternative mortgage contracts with built-in features designed to assist households overcome periods of financial distress. Eberly and Krishnamurthy (2014) propose a fixed rate mortgage (FRM) with a one-time option to convert to an adjustable-rate mortgage (ARM). Guren et al. (2017) develop an equilibrium model of the housing market and compare the Eberly-Krishnamurthy convertible mortgage contract to a FRM with an option to costlessly refinance to another FRM. They find that the option to con-

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\(^{69}\) Once borrowers regain their footing, they can always make the higher mortgage payments they would have owed under the less generous modification and avoid the larger payments at the end of the mortgage term. On the other hand, behavioral biases could make borrowers less likely to depart from the status-quo and make higher payments than required under their modified contracts even when it might be optimal for them to do so.

\(^{70}\) With no change in the default rate or prepayment risk, a maturity extension is NPV negative (positive) to the lender if the lender’s current discount rate is higher (lower) than the interest rate on the loan being extended.
vert to an ARM outperforms the option to refinance to a FRM specifically because relative to the refinance option, the conversion to an ARM front-loads the payment reduction to the borrower, and does so at similar cost to the investor. Our results provide empirical evidence that contracts front-loading payment reductions to households in financial distress will be more effective at preventing defaults than an alternative contract with equal cost to the investor that spreads payment reductions throughout the mortgage term. Similarly, Clara and Cocco (2016) compare an ARM with a refinance option to an ARM with the option to temporarily allow for interest-only payments, with a corresponding increase in its maturity. They find that this maturity extension option outperforms a refinance option because it provides similar liquidity-provision benefits to borrowers at much lower cost to investors. Our results show that immediate payment reduction can indeed be effective at reducing defaults even if structured with offsetting payments in the future so as to minimize costs to investors.

B.6 Effect of Payment Reduction on Consumption

Our payment reduction regression discontinuity empirical strategy is under-powered for studying consumption impacts. In Appendix Figure B.9 we plot the reduced form of the 31% PTI strategy with the change in mean credit card spending from the year before modification to the year after modification as the outcome variable. The standard error is so large that, using the same procedure for calculating an MPC as described in section 4.5, we cannot rule out an MPC above 1 or below -1.

Unlike with principal reduction, we are unable to increase the precision of our payment reduction estimates by using a difference-in-differences design. The difference in principal reduction received by borrowers with and without principal reduction remains large when we expand the sample to a wider bandwidth. In contrast, the difference in payment reduction between HAMP and Chase modifications falls when looking at a wider sample (as can be seen by looking at the edges of the top panel of Figure B.1). This is because the PTI target in HAMP generates larger payment reduction for higher PTI borrowers. Hence comparing borrowers who received HAMP and Chase modifications at a wider bandwidth results in a shrinking treatment size. We therefore conclude that our data and available research designs are unsuited for credibly estimating the effect of payment reduction on consumption.
B.7 Payment Reduction Figures

Figure B.1: Effect of Payment Reduction on Default Using 31% PTI Cutoff

Notes: This figure shows the estimated effect of payment reduction on default using the 31% PTI regression discontinuity in the JPMCI bank dataset. The top panel plots the first stage, with payment reduction on the vertical axis and borrower PTI on the horizontal axis. The blue dots are conditional means for 12 equally spaced bins on each side of the cutoff. The red line shows the predicted value from a local linear regression estimated separately on either side of the cutoff. The RD estimate is the jump in predicted values at the cutoff, corresponding to an estimate of the numerator in equation (7). The bottom panel plots the reduced form, with the default rate on the vertical axis and borrower PTI on the horizontal axis. Default is defined as being 90 days delinquent at any point within two years of the modification date. Construction of the IV estimate $\hat{\tau}$ is described in section B.2.
Figure B.2: Financial Impacts of Modifications Around 31% PTI Cutoff

Notes: The top panel plots the difference in average annual payments relative to the pre-modification mortgage for borrowers with PTI ratios from 30%-31% and from 31.1%-32.1% in the JPMCI bank dataset. The bottom panel summarizes the financial impacts of modifications along various dimensions for borrowers above and below the cutoff.
B.8 Payment Reduction Appendix Figures

Figure B.3: Structure of Mortgage Modifications

Notes: This figure plots the average annual payments owed under the status quo and under the modified mortgage contracts for borrowers receiving Chase mortgage modifications in the JPMCI bank dataset. This includes all borrowers in our sample with PTI ratios between 25% and 38%.
Figure B.4: Robustness of Payment Reduction Result to Inclusion of Mixed Treatment Group

**RD — First Stage**
Dependent Variable: Change in Mortgage Payment from Mod (%)

RD Estimate:
16.2 (0.4)

**RD — Reduced Form**
Dependent Variable: Default

IV Estimate of 1% Payment Reduction:
0.0024 (0.0007)

Notes: This figure shows the estimated effect of payment reduction on default using the 31% PTI regression discontinuity in the JPMCI bank dataset, including observations with PTI between 31% and 31.1% which are dropped in the main analysis. The top panel plots the first stage, with payment reduction on the vertical axis and borrower PTI on the horizontal axis. The blue dots are conditional means for equally spaced bins on each side of the cutoff. Bins are four times narrower than in the baseline figures in order to visually capture the loans right at the cutoff. The red line shows the predicted value from a local linear regression estimated separately on either side of the cutoff. The RD estimate is the jump in predicted values at the cutoff, corresponding to an estimate of the numerator in equation (7). The bottom panel plots the reduced form, with the default rate on the vertical axis and borrower PTI on the horizontal axis. Default is defined as being 90 days delinquent at any point within two years of the modification date. Construction of the IV estimate \( \hat{\tau} \) is described in section B.2.
Figure B.5: Modification Characteristics Around the 31% PTI Cutoff

Notes: This figure shows the amount of principal reduction received around the 31% PTI regression discontinuity cutoff in the JPMCI bank dataset. The blue dots are conditional means for 12 bins on each side of the cutoff. The red line shows the predicted value from a local linear regression estimated separately on either side of the cutoff. The RD estimate is the jump in predicted values at the cutoff, corresponding to an estimate of the numerator in equation (7).
Figure B.6: Initial Borrower and Mortgage Characteristics Around the 31% PTI Cutoff

Notes: This figure shows average pre-treatment characteristics around the 31% PTI regression discontinuity cutoff in the JPMCI bank dataset. The horizontal axis shows pre-modification borrower PTI. The vertical axis in the first four panels shows the ratio of unpaid principal balance to the market value of the house (mark-to-market loan-to-value ratio), the number of months past due at modification date, monthly income, and monthly payment. The final panel shows predicted default rates from a linear regression of default on the first four borrower characteristics. The blue dots are conditional means for 12 bins on each side of the cutoff. The red line shows the predicted value from a local linear regression estimated separately on either side of the cutoff. The RD estimate is the jump in predicted values at the cutoff, corresponding to an estimate of the numerator in equation (7).
Figure B.7: Borrower Density Around the 31% PTI Cutoff

Notes: This figure plots the histogram of the running variable from our 31% PTI regression discontinuity strategy in the JPMCI bank dataset. The horizontal axis shows pre-modification borrower PTI. The top panel shows borrowers with PTI ratios between 25% and 37%, dropping the 250 observations between 31.0% and 31.1%. This is our main analysis sample. The bottom panel shows the density for the full sample.
Figure B.8: Effect of Payment Reduction on Default Using Alternative Bandwidths Around the 31% PTI Cutoff

Impact of Payment Reduction on Default

Notes: This figure plots the estimated reduced form jump in default and the associated 95% confidence interval at the 31% PTI regression discontinuity cutoff calculated using alternative bandwidths in the JPMCI bank dataset. The Imbens and Kalyanaraman (2012) optimal bandwidth is 0.45.
Figure B.9: Effect of Payment Reduction on Credit Card Expenditure Using the 31% PTI Cutoff

Impact of Payment Reduction on Credit Card Spend
Regression Discontinuity

IV Effect of $1 of Payment Reduction:
−0.129 (0.114)

Notes: This figure shows the reduced form of the estimated impact of payment reduction on credit card expenditure using the 31% PTI regression discontinuity strategy in the JPMCI bank dataset. The blue dots are conditional means for 12 bins on each side of the cutoff. The red line shows the predicted value from a local linear regression estimated separately on either side of the cutoff. Construction of the IV estimate \( \hat{\tau} \) is described in section B.2. This strategy is unable to detect economically meaningful changes in expenditure.