Online Appendix for "Payment Size, Negative Equity, and Mortgage Default"

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A A simple model of mortgage default

This section presents a barebones model of a borrower's default decision, in order to derive qualitative predictions for what we should expect to see in the data. This model is a simplified version of other frictionless models in the literature, such as Kau et al. (1992).

We consider the following transaction. A homeowner owns a house priced S_0 and gets a three-period mortgage. The terms of the loan are that the lender advances some amount L_0 at time 0 and the borrower promises to make a periodic payment of m dollars at time 1 and to repay e dollars at time 2. The house price evolves stochastically but the payments m and e are deterministic. There is a market interest rate r and the borrower can borrow and lend unlimited amounts at that rate. If the borrower fails to pay m at time 1 or e at time 2, the lender sells the house to recover the money owed. We abstract here from the possibility of prepayment but this is, otherwise, a standard promissory note: the borrower promises to make a series of payments and the lender sells the collateral in the event that the borrower defaults. There are no frictions and the lender has no recourse to the borrower's other assets nor are there penalties for default. At time 1 the borrower can, if he so desires, default on his promised payment and buy an identical house with a new, smaller mortgage.

We now show three key propositions about mortgages. First, we show that we can characterize the mortgage described above as a call option on a call option on the house. Second, we show that negative equity is basically never sufficient for default to be optimal except in a situation where a borrower with negative equity at time t also has negative equity for all $s > t$ along every possible path for prices. And third, we show that changes in the size of the monthly payment affect repayment behavior more when borrowers have negative equity than positive and that for any reduction in principal, there is an equivalent reduction in the monthly payment that will reduce default by the same amount.

We stress that the purpose of this model is not to describe an actual borrower's decision. At the very least, a complete description of the borrower's choice would include borrowing limits on the riskless asset, liquidity shocks, and some sort of penalty for default. A more sophisticated model would differentiate the consumption of housing from that of other goods.[1] For our purposes, one can think of the household as having some fixed level of housing consumption and assume that the payments made by the borrower are net of rent. In other words, at time 1, the borrower actually pays $r+m$ on the mortgage and r if he opts to default. Despite these omissions, the model described below illustrates some basic principles of the mortgage default problem that apply in any model and also some common errors that economists and others make in thinking about the problem.

A.1 A formal model

Consider a three-period model with $t = 0, 1, 2$, with a finite sample space $\Omega = \{\omega_1, ..., \omega_K\}$, with a probability measure P, and a filtration $\mathcal{F}$. Suppose we have a security S with adapted price process $S_t, t = 0, 1, 2$ and a riskless asset with return r. Let M be a security in which the investor gets the option to pay m at time 1 for an option to buy security S at time 2 for price e. Let C be a call option on the house with strike price e exercised at time 2. Let M be a call option on C with strike price m exercised at time 1. Importantly, we assume absence of arbitrage, which implies the existence of an equivalent martingale measure Q defined on $\mathcal{F}$ and Ω. For simplicity, we assume the borrower does not discount the future.

Our first insight is that selling the house and buying the call option M at time 0 is an identical problem to the mortgage choice problem described above. The coincidence of these two strategies is a simple example of put-call parity and results from the fact the mortgage contract includes an embedded put option. To see the mechanics, start at time 2. If the borrower made the mortgage payment m at time 1, then his payoff would be:

$$(S_2 - e)^+,$$

which is also the payoff for the call option C, which the investor has the option to buy for price m. In other words, buying the call option and making the mortgage payment at time 1 are identical investments. At time 0, the borrower receives L_0 by receiving a loan of that amount and the buyer of M also receives L_0, but, in his case, it comes from selling the house for S_0, paying M_0 for the call option.

[1] See e.g. Campbell and Cocco (2015) for a more realistic model of the default decision.

A.2 Equity and default

Going forward, we focus on the call option formulation, as it is far easier to work with. We now turn our attention to the question of the relationship between negative equity and default. As explained above, default at time 1 consists of failing to exercise the call option M. That is to say:

$$\text{Borrower Defaults} \Leftrightarrow C_1 < m. \tag{4}$$

What is surprising and somewhat counterintuitive is that neither the price process of the house S nor the outstanding balance of the loan e appear in equation (4). But, of course, C_1 depends on S, and, by absence of arbitrage, we can re-write equation (4) as

$$\text{Borrower Defaults} \Leftrightarrow C_1 = \frac{1}{(1+r)} \mathrm{E}_Q \left(S_2 - e\right)^+ < m. \tag{5}$$

Equation (5) allows us to establish a proposition that is central to understanding the default decision:

Proposition 1 *If and only if there exists $\omega \in F \in \mathcal{F}_1$ such that $S_2(\omega) > e$, then there exists $m > 0$ such that $C_1 > m$ and default is not optimal.*

Proposition 1 leads to two significant conclusions. First, suppose all we observe about a borrower is that he has negative equity, that is, that $S_1 < e$. What can we say about whether it is optimal to default? Not much. The sufficient condition for default is that the borrower must have negative equity in every possible future state of the world, and $S_1 < e$ is not a sufficient condition for that. In fact, the historical evolution of house prices indicates that nominal house prices often surpass their previous peaks over fairly short horizons even after deep busts. In other words, negative equity today has not, historically, been sufficient to eliminate the possibility of positive equity at some point in the future.

The second key point, and the one most relevant to this paper, is that as long as there is some state of the world in which the borrower has positive equity, then that borrower will continue making mortgage payments if we lower the payment enough. So long as $C_1 > 0$, then, we can set the payment at $C_1/2$ and ensure continued payment.

Before continuing, it is important to stress that we have not, in any way, ruled out the possibility that the borrower could opt against exercising M and go and buy another house with a new mortgage. However, the existence of such a strategy has no effect on our results; as long as there is no arbitrage, it is *always* the case that if $C_1 > m$, "walking away" and making any other investment is strictly wealth reducing relative to exercising the call option.

To see why, note that if $C_1 > m$, then the borrower has an opportunity to buy an asset worth C_1 dollars but pay less than C_1. By exercising the option the borrower increases his wealth by $C_1 - m$ dollars. What investment could possibly dominate that? No investment. Unless an arbitrage opportunity exists, the most valuable alternative investment a borrower can make with the m dollars will be worth m dollars, which is strictly less than C_1 and thus will reduce the borrower's wealth.

We conclude this discussion of negative equity by making one thing crystal clear. Proposition 1 does not imply that borrowers will never default. For a fixed m, a sufficiently large fall in prices will reduce the value of the call option so that $C_1 < m$ and default is optimal. But to deduce that default is optimal for a given borrower, we need to know the borrower's beliefs about the stochastic process for house prices, the discount rate, and the size of the monthly payment and, in a multi-period world, future monthly payments. Thus, the existence of borrowers with negative equity making their monthly payments is fully consistent with rationality in every sense.

A.3 Taking the model to the data

What does our simple model tell us to expect in the data? First, as we have already explained, Proposition 1 implies that unless there is no state of nature in which the borrower will have positive equity, borrowers will continue to make mortgage payments if the monthly payment is sufficiently low. Furthermore, changes in the monthly payment will affect repayment behavior, no matter how negative the equity. In fact, in the extreme, payment reduction should be *more* effective, the more negative the equity. To formalize this, imagine that we have a continuum of borrowers with the same S_1 and e but indexed by different levels of C_1. If $S_1 - e > m$, then $C_1 > m$ for all i and no borrower will want to default, meaning that perturbing the monthly payment will have no effect on default behavior. For lower levels of equity and a sufficiently high monthly payment, a small perturbation of the monthly payment should have no effect but a sufficiently large change will always affect borrower repayment behavior.

We can also think about the dynamics of default using the model. Up to now, we have focused on the decision to default at time 1, but we can think about default at time 0 by imagining that the borrower has to pay m_0 to buy security M at time 0. The default decision at time 0 is

$$\text{Borrower Defaults} \Leftrightarrow M_0 < m_0, \tag{6}$$

which, by absence of arbitrage is

$$\text{Borrower Defaults} \Leftrightarrow M_0 = \frac{1}{(1+r)} \mathrm{E}_Q \left(C_1 - m\right)^+ < m_0. \tag{7}$$

Default at time 0 obviously depends on the level of the current payment m_0 but also on the future payment m. In other words, a future reduction in the monthly payment should affect current willingness to pay.

B Additional details on the data

In this section, we describe a few more details about our data.

Information on ARMs. For ARMs, the information about the terms of the loan includes the number of months after which the loan resets for the first time, the frequency of subsequent resets (6 or 12 months), the interest rate to which the loan is indexed (most commonly the 6-month LIBOR), the margin over the index rate (most commonly 225 basis points), and bounds on the admissible level of or changes to the interest rate (commonly referred to as "caps" and "floors").[2] The information provided is (nearly) sufficient to predict the evolution of the interest rate as a function of the index to which it is linked. The only piece of information that is missing is the exact date at which the index rate is taken to determine the borrower's subsequent interest rate after the reset. When imputing interest rates (or forecasts thereof) we assume that the relevant index rate is taken as of the first business day of the month, which appears to be the most common contract specification.

Choice of origination date range. Our origination date range (January 1, 2005 to June 30, 2006) was chosen for two reasons. First, when these loans reset, the majority of them see large reductions in interest rates, as the 6-month and 1-year LIBOR as well as the constant-maturity 1-year Treasury bill rate, since the short-term rates to which these loans are indexed when they reset have been very low since early 2009 (see Panel A of Figure 2), after an initial drop in early 2008. Second, for those that have reset (the 3/1s and 5/1s), we have at least an additional five months of performance data (unless they prepay or foreclose, of course).

Other sample restrictions. We retain only first-lien mortgages on single-family homes and condominiums, with origination amounts between \$40,000 and \$1,000,000 (roughly corresponding to the 1st and 99th percentile of our initial sample) and with an origination LTV

[2] An example from an actual loan contract: "The interest rate I am required to pay at the first Change Date will not be greater than 12.625% or less than 2.25%. Thereafter, my interest rate will never be increased or decreased on any single Change Date by more than Two percentage points (2%) from the rate of interest I have been paying for the preceding six months. My interest rate will never be greater than 12.625%."

between 20 and 100 percent. Also, we restrict our sample to loans that enter the dataset within six months of origination, in order to minimize selection bias.

Censoring. When estimating the Cox model for delinquency, we treat mortgages that prepay as censored, and vice-versa. In both cases, we also treat mortgages as censored when they are marked in the LP data as being subject to a loan modification, which often leads the mortgage to become a fixed-rate mortgage or to reset at different dates than those specified in the original contract. Only about 3,000 uncensored loans in our data are modified while current or 30-days delinquent. Importantly, we also treat as censored mortgages that are subject to an interest rate *increase*; as explained in Section I, such upward resets give rise to potentially important selection biases. That said, in our data only about 15,000 loans ever see their interest rate increase, most of them at either age 37 or 43 months (for 3/1s) or 67 months (for 5/1s).

Timing of delinquency measure. We use the standard MBA (Mortgage Bankers Association) definition of delinquency. Specifically, the MBA definition says that a borrower's delinquency status increases by 30 days every time he fails to make a scheduled payment before the next payment is due. For example, using the MBA method, a servicer would report a borrower who is current, has a payment due on June 1 and makes no payments in June as current in June and 30-days delinquent in July. Depending on whether the borrower makes no payment, one payment, or two payments in July, he will transition to 60 days, stay at 30 days or become current, respectively.

C Defaults: Robustness and subsamples

In this section, we provide a number of robustness checks on our main default regression specification from Section III. We address three potential issues: (1) differential pre-reset trends across different loan types; (2) correlation in the size of the reset with unobservable variation in borrower characteristics; (3) differential responses across loan types to changes in macro conditions. In addition, we discuss a variety of other alternative specifications.

One potential concern in our setting is that loans of different types may have differential pre-reset trends in default hazards (in a way not absorbed by the loan-type-specific calendar quarter dummies), and that including data away from the resets biases the estimated effects. In our baseline specification, we do not use the first 30 months of data, in order to make sure they do not drive the estimated effects.[3] Focusing on the stark resets of the 5/1s relative to the 7/1+ loans, Panel D of Figure 4 in the main paper already provided graphical evidence

[3] As column (2) of Table A.1 shows, however, the results are very similar if we do include the first 30 months after origination.

that there are no differential pretrends between these loan types and that the relative hazard of the 5/1s drops sharply after the reset.[4] To further investigate this point, we conduct an "event study" of the effect of the 5/1 reset, by retaining only five months of data before and after the reset, and by comparing only the 5/1 and the 7/1+ loans. The resulting coefficient estimates are shown in Column (1) of Table A.2 and indicate that for the common rate reductions of 2.5 percentage points or more, the estimated effects are very similar in size to those in the baseline specification. (The effects for smaller rate reductions are very imprecisely estimated in this specification, since there are only few 5/1s with such small rate reductions at the reset.)

A second potential concern is that our estimates are confounded by a type of selection different from the one discussed in Section I: the size of the reset for borrowers within a loan type may be affected by the riskiness of a borrower. For instance, riskier borrowers get higher initial interest rates and therefore larger resets (assuming they have no binding rate floor). There is also some heterogeneity across borrowers in terms of index rates, margins, and rate floors. To eliminate this potential confound, we re-run our regression using the median interest rate (relative to the initial rate) of loans of the same type and originated the same month as loan i in lieu of loan i's actual relative interest rate. The resulting coefficients, shown in column (2) of Table A.2, are overall again similar to those in the baseline, meaning that the relevant variation comes from only two sources: when a loan was originated, and how long its fixed-rate period was.

The third main concern is that different loan types are differentially sensitive to changes in economic conditions—for instance, the default hazard of 5/1 borrowers relative to that of 7/1+ borrowers could fall around the time of the 5/1 resets (in 2010 and 2011) because the economy improves around that time and the borrowers who chose the 5/1s, who are riskier than those in the 7/1+ loans, may benefit more from this improvement in economic conditions. However, this effect would be soaked up in the loan type $\times$ calendar quarter dummies, so it should not affect the estimated effect of the rate reduction.[5]

Furthermore, we note that the estimation does *not* need to rely on the inclusion of the 7/1+ loans as comparison group: we can also identify the effects of resets solely from comparing the 3/1 loans, which start resetting 37 months after origination, to the 5/1 loans. Comparing these two loan groups is appealing because they are very similar in terms of origination char-

[4]Recall from Section II.D that the reset of the 5/1 loans, which for the majority of them occurs in month 61 (but in some cases is marked in the data as occurring in months 60 or 62) becomes directly relevant for the delinquency status two months later, i.e. generally in month 63. The fact that the relative hazard starts dropping in month 60 is consistent with "anticipation effects" as discussed in the Section III.B.

[5]Not including these interacted dummies, as done in an earlier version of this paper, leads to slightly larger estimated effects of the rate reduction. Using calendar month instead of quarter barely affects the results, but significantly increases the time it takes for the maximum likelihood estimation to converge.

acteristics, and also because their default hazards over the first 30 months track each other quite closely. What is particularly interesting, however, is that the relative rate differences between 3/1s and 5/1s vary across origination cohorts, both in magnitude and in timing, and we can check visually whether this variation is also reflected in relative default hazards. This is done in Figure A.1. This figure shows, for each of the six origination-quarter-vintages, how the differences in average rates between 3/1s and 5/1s (top line), as well as the relative default hazards of 3/1s (bottom line), change over (calendar) time.[6] The relative performance of 3/1s and 5/1s is closely aligned with the resets: when the rate of the 3/1s falls, they default less than the 5/1s; once the 5/1s also reset down, the relative performance of the 5/1s improves. Also, this clearly happens at different calendar times for different vintages, going against the hypothesis that the effect we pick up in the aggregate is driven by differential sensitivity of the different loan types. Quantitatively, Table A.2 shows that removing the 7/1+ loans from the sample, and only identifying the effects of interest rate changes from the 3/1s and 5/1s, leads to very similarly sized effects as in our baseline. The same is true if we alternatively drop the 3/1s or the 5/1s (columns (3) to (5)).

The remaining two columns of Table A.2 show two additional specifications that validate our discussion in Section III.A of potential heterogeneity of the effects. In column (6), we repeat our baseline regression but including only the loans with estimated CLTV $>$ 140. This is similar to the specification with interaction terms that we focused on in the main text, but allows all other regression coefficients to be specific to this sample of loans. The column shows that the estimated effects of the rate reduction are very similar to those in the full sample but, if anything, slightly larger, in line with our discussion in the main text. Column (7) restricts the sample to a sample of borrowers with "prime" characteristics — a high ($\geq$ 740) FICO score and providing full documentation at origination. This lowers the sample size to below 8,000 loans and thus reduces the precision of the estimates. In line with our findings from the interaction regressions in Section III.A, and also from the separate prime sample (see Appendix D), the point estimates suggest that the delinquency of these borrowers could be slightly less responsive to interest rate decreases than what we observe for the whole sample. That said, the estimated effects remain very large.

[6] To reduce noise, we plot three-quarter moving average relative default hazards, and to enhance comparability across cohorts, we normalize the relative hazard to 1 for the tenth quarter of each cohort's history.

D Analysis on sample of prime loans

In this section, we provide evidence that the large effects of rate reductions on defaults are not limited to the Alt-A sample we study in the main text. To do so, we have obtained a sample of privately securitized *prime* loans with otherwise the same contract characteristics, origination and observation time periods as in our main analysis. Again, the dataset comes from CoreLogic LoanPerformance (LP).

Over this origination period, 80 percent of loans in the LP prime data are jumbo loans, meaning their origination amount is above the conforming loan limits such that they could not be securitized by Fannie Mae or Freddie Mac. The market shares of different loan types are as follows: FRMs 39.5 percent, 5-year IO ARMs 22.4 percent, 10-year IO ARMs 20.6 percent, regularly amoritizing ARMs 9.5 percent, with the remainder going to other types of IO ARMs, balloons, etc. As in the main paper, we focus on the 10-year IOs, since 5-year IOs with a 5-year fixed rate period often seen their payment roughly unchanged at the time of the reset (while for the 10-year IOs the payment drops in line with the rate reduction).

Table A.3 shows descriptive statistics on our prime sample, which is only about one-quarter as large as the Alt-A sample from our main analysis. Also, as Panel A shows, the fixed-rate periods tend to be longer; more than two-thirds of the loans are in our "control group," the 7/1+ segment.

Panel B shows other descriptive statistics, which can be compared to those in the corresponding panel of Table 2 in the main paper. Aside from the larger origination amounts, we note that the loans in the prime sample have lower origination LTVs and CLTVs, and the borrowers have higher FICO scores, making the loans less risky than those in the Alt-A sample. Panel C shows that these borrowers on average remained less underwater than the borrowers in the Alt-A sample, even though many of them also experienced steep house price declines.

Panel D shows that the outcomes in this sample are much better than for the Alt-A loans—the fraction of loans to ever become 60-days delinquent is 60 percent lower. Thus, any concerns that the sample in the main paper is "unrepresentative" because of the high riskiness of the borrowers should be mitigated in this sample of prime loans.

Panel A of Figure A.2 shows the default hazard of 5/1 and 7/1+ prime loans by loan age.[7] The qualitative pattern is very similar to the one in the Alt-A sample (shown in Panel B of Figure 1 of the main text): the default hazard of the 5/1 loans is much higher than that of the 7/1+ loans prior to the reset in month 61; afterwards, the pattern is reversed and the 5/1s are

[7] Due to the small number of 3/1 loans in the sample, the default hazard for this group is very volatile and thus not shown.

less likely to default.

Panel B displays the estimated hazard ratios associated with different rate reduction bins and CLTV bins from the same baseline regression specification as in the main text; the full results are shown in column (4) of Table A.1. The coefficients on small reductions are very imprecisely estimated due to the small number of loans in these bins, but for large reductions (2 percentage points or more) the coefficients are overall very similar to the ones in the Alt-A sample.[8] The coefficients on the CLTV bins are also of similar magnitude, though they suggest that default probabilities are somewhat more sensitive to CLTV in the prime sample than in the Alt-A sample.

In sum, the analysis of ARM borrowers in the prime sample indicates that our finding of large reductions in default hazards after a cut to the required monthly payment is not limited to the sample of Alt-A borrowers analyzed in the main text, but extends also to prime borrowers. This is in line with other recent empirical papers cited in the main text (Tracy and Wright, 2016; Zhu, 2012; Keys et al., 2014; Ehrlich and Perry, 2015).

E Upward resets

In this section, we expand on our discussion in Section I.B of the paper by studying the effects of payment increases in a sample of Alt-A 3/1 IO ARMs originated in the first half of 2004. These loans are similar to the loans in our main sample with the difference that when they first reset in 2007, interest rates were still high. Indeed, Panel A of Figure A.3 shows that for these loans, average rates went from 5.0 to 7.5 percent at the time of the first reset in month 37.

Panel B of the figure shows two different measures of defaults for the 2004:H1 sample, both normalized relative to month 36. The dashed line reports the default hazard and shows that the default hazard jumped three-fold after the reset and remained relatively high afterward (though with substantial fluctuations due to a relatively small sample). In addition, the default hazard at the time of the reset was already elevated relative to where it was in the first year of the loan. From this information, one would infer that the reset had a big effect. However, the solid blue line reports the *number* of defaults and shows a relatively modest change at the time of the reset. For three months, defaults are elevated by about 50 percent relative to immediately prior to the reset but overall, the contribution of the reset to the overall number of defaults appears to be relatively small.

Panel C shows the prepayment hazard for the 2004:H1 sample. The notable feature is, of course, the spike that occurs around the time of the reset. Anticipating or following the

[8] The exception is the coefficient on the $(-3.5, 4]$ bin, which is however quite imprecisely estimated.

payment increase, a large fraction of the borrowers opted either to refinance or sell their homes; in fact, the size of the remaining loan pool dropped by more than half between month 34 and month 40. The behavior of prepayments explains the gap between the evolution of the default hazard and the number of defaults. The increase in the default hazard results not from an increase in the numerator—the solid line—but from a big fall in the denominator.

Panels A and B again show that a large change in the default hazard is completely consistent with a small change in the number of defaults. Thus, the data from the crisis showing that upward resets occurring until 2007-8 led to only a small increase in the number of defaults (Sherlund, 2008; Foote, Gerardi, and Willen, 2012) do not contradict the possibility of upward resets having an economically large effect on the default hazard. However, as we explained in Section I.B, it is very difficult to precisely estimate how large the treatment effect of the upward reset is, since it is confounded by selection effects due to non-random prepayments.

We now show a way to calculate bounds on the treatment effects of the upward resets that is more general than the example in the main text. In Section I.B we defined the true effect of the payment shock as ϕ and showed that the evolution of the hazard, d_{t+1}/d_t, would overstate ϕ if $\sigma_{t+1} - \sigma_t > 0$. The conditions under which this occurs can be seen from the law of motion for the share of bad borrowers:

$$\begin{aligned}\sigma_{t+1} - \sigma_t = & \quad \frac{\sigma_t(1 - p_t^b - d_t^b)}{\sigma_t(1 - p_t^b - d_t^b) + (1 - \sigma_t)(1 - p_t^g - d_t^g)} - \sigma_t \\ = & \quad \sigma_t \left[\sigma_t + (1 - \sigma_t) \cdot \frac{1 - p_t^g - d_t^g}{1 - p_t^b - d_t^b}\right]^{-1} - \sigma_t.\end{aligned} \tag{8}$$

This expression will be positive if $p_t^g + d_t^g > p_t^b + d_t^b$, that is, if a larger fraction of good borrowers than bad borrowers leaves the population during period t. Assuming this is the case, it follows then that the ratio d_{t+1}/d_t is an upper bound on ϕ.

To get a lower bound, let D_t be the number of defaults at time t. Then, we get

$$\frac{D_{t+1}}{D_t} = \phi \left[1 - \frac{d_t^b \sigma_t (p_t^b + d_t^b) + d_t^g (1 - \sigma_t)(p_t^g + d_t^g)}{d_t^b \sigma_t + d_t^g (1 - \sigma_t)}\right]. \tag{9}$$

The expression in brackets is smaller than 1, making D_{t+1}/D_t a lower bound on ϕ. Intuitively, the upper bound provides an unbiased estimate of ϕ if there is no selection over time (if $d_t^b = d_t^g$ or $p_t^g + d_t^g = p_t^b + d_t^b$), while the lower bound is close to ϕ if exits from the pool are approaching zero.

Using the above, one can re-interpret the data in Panel B as showing that the treatment effect of the reset was between roughly 1.5 and 3 in months 39-42. One can conduct a similar exercise in our main sample where rates decrease and prepayments do not spike. Panel D presents the bounds for the 5/1 ARMs in our main sample and illustrates the success of our identification strategy at dealing with the potential selection issue as the upper and lower bound are almost exactly the same, a consequence of the minimal levels of prepayment around the reset.

Finally, based on these findings we can do an imperfect comparison of the effects of upward and downward resets. Focusing on the immediate aftermath of the reset, interpreting the data in Panel B as bounds shows that the 2.5 percentage point increase in rates led to an increase in the default hazard of between 1.5 and 3 times. In our main analysis, we estimate that a 2.5 percentage point drop in rates cuts the default hazard in half (see Figure 3), roughly the inverse of the midpoint of the range for the effect of the upward reset. This evidence is thus consistent with the idea that upward and downward resets have symmetric treatment effects on the default hazard, but it is difficult to make more precise statements because due to the prepayments we cannot tightly bound the effects from the upward resets.[9]

F The incidence of default

The results in Section III of the paper show that interest rate reductions i) strongly reduce the default hazard, even for borrowers who are deeply underwater, and ii) also strongly reduce the prepayment hazard, although this is relative to a lower base rate than for the default hazard. In this appendix section, we illustrate the combined effect on the cumulative number or *incidence* of defaults, which is affected by both default and prepayment hazards (because a loan that prepays can no longer default). To do so, we use our estimated coefficients to predict the cumulative fraction of delinquency for a fixed population of 5/1 loans with certain characteristics, starting at loan age 55 months.

The loan characteristics we chose are shown in Panel A of Figure A.4. These are close to the modal characteristics of loans that are still in the sample at age 55. Panel B shows the cumulative incidence of 60-day delinquency implied by the combination of our estimated baseline default and prepayment hazard models, with and without a 3-percentage point reduction in the interest rate occurring at loan age 61 months, and for two different assumptions about a loan's CLTV.[10] The upper two lines show that for a CLTV between 130 and 140, our

[9]The fact that the increase in the default hazard following the upward reset is somewhat larger than what is implied by our estimated treatment effects from the main analysis is consistent with the idea that the borrowers that are left in the sample after the upward reset are of worse quality, as hypothesized in Section I.

[10]In calculating the competing hazards, we take equal-weighted averages across the possible origination months, thereby accounting for the fact that the baseline hazards are allowed to vary at the origination-quarter

estimates imply that at the initial interest rates, about one-third of loans that are not delinquent at age 55 would become 60-days delinquent by age 75. With the 3-percentage point reduction at the reset, however, this predicted fraction goes down to about 23 percent. If we compare the predicted incidence of delinquency only after loan age 63, when the reset becomes relevant, we see that only about 8 percent of loans become delinquent with the reset, but that about 17 percent become delinquent without the reset. Thus, over the span of one year after the reset, a 3-percentage point reduction, which corresponds approximately to cutting the payment in half, is predicted to reduce the incidence of default by about 9 percentage points, or more than 50 percent.

The lower set of lines in Panel B shows the predicted cumulative incidence of delinquency for loans that are not underwater, with a CLTV between 80 and 90. Unsurprisingly, such loans are predicted to go delinquent at a much lower though still non-trivial rate. While without the reset at age 61, the model predicts that about 14 percent of loans go delinquent by age 75, with the reduction the predicted fraction is below 10 percent. While the relative impact on delinquency rates is similar to the impact for the underwater loans, the absolute reduction in the number of delinquent loans due to the reset is much lower than for underwater loans.

Finally, one might think that the model-implied incidence of delinquency seems unreasonably high, but Panel C shows that this is not the case. The panel shows the actual cumulative fraction of loans with a CLTV above 130 at loan age 55 that become 60-days delinquent by age 75, for our three different loan types. We see that among loans in the ARM 7/1 and 10/1 category, one quarter become 60-days delinquent over that time span. For 3/1s, which have benefitted from a number of downward rate resets, the corresponding number is below 20 percent. Most interestingly, the 5/1s, to which the counterfactuals in Panel B apply, were on a higher path than the 7/1+ loans prior to loan age 61, and it is plausible that 30 percent or more of these loans would have become delinquent without the reset. However, in actuality we see a notable change in the slope of the incidence function for these loans around age 62 (with a slight reduction in the slope already occurring around age 60, consistent with the findings from Section III.B), so that by age 75 fewer than 20 percent defaulted.

G Cures

In this section, we describe our analysis of "cures" of delinquent mortgages. A cure occurs if a borrower who was 60 or more days delinquent becomes current again, or prepays the loan voluntarily (that is, not by defaulting). Note that to cure, the borrower cannot simply resume

level and that our regressions include calendar-quarter effects.

making scheduled payments but must remit all the missed payments as well.

To study the determinants of cures of delinquent mortgages, we again use a Cox proportional hazard model, this time using only the population of loans that is 60+ days delinquent. The possible competing outcomes are now $n \in$ (cure, foreclosure, modification). The index t now refers to the number of months a loan has been delinquent, since the number of periods a loan has been in delinquency will strongly affect the likelihood that it cures. Similarly, the interest rate R_{it} is now measured relative to the rate at which the borrower became delinquent (rather than relative to the initial rate). Our regression specification includes dummies for each loan age to allow for age dependence in the likelihood of cures. We retain all "delinquency episodes" that start with a 60-day delinquency; if a borrower cures after his first episode, he may appear in more than one episode.

Figure A.5 shows the results of our baseline specification and, as with the defaults, formal statistical analysis confirms the visual evidence in Panel C of Figure 1 and shows that rate changes have statistically and economically significant effects on the likelihood of cure.[11]

The top panel of Figure A.5 shows that a 2–2.5-percentage point reduction in the interest rate leads to a 75-percent increase in the cure hazard, and a 3-point or higher reduction more than doubles the probability of cure. As with the default hazard, the effect of payment reduction is comparable to the effect of large changes in CLTV, with the same caveats about the interpretation of such changes. Also, as shown in column (2) of Table A.4, negative equity does not attenuate and may in fact enhance the effect of rate reduction on cures. For instance, for borrowers with CTLV> 140, the estimated effect of a 3-percentage point rate reduction increases from 200 percent to about 240 percent. Column (3) of the table shows that the estimated effects are similar when only the rate controls are included.

One might worry that the measured effect of rate reductions on cures is confounded by concurrent changes in servicers' propensity to modify delinquent loans. If, for instance, servicers tended to modify the loans that are most likely to cure (even without a modification), and then reduced the number of loans they modify after the interest rates decrease, then the measured effect of rate reductions on cures would be due at least in part to selection. Columns (4) to (6) of Table A.4 shows that we find little systematic effect of rate reductions on the probability of a loan's receiving a modification.

[11] The cure rate in Panel C of Figure 1 may seem low; this is due to the fact that the denominator includes all 60+ days delinquent loans that have not foreclosed yet (including those that are in the foreclosure process). In unreported analysis, we have also looked at (only) newly 60-days delinquent loans separately, and find results that are consistent with those reported in this section. Newly delinquent loans have a much higher cure rate, which, for 5/1s, goes from about 12 percent in month 50 to a high of 30 percent after the reset.

Figure A.1: Timing of rate resets and defaults hazards of 3/1s vs. 5/1s

Figure shows how the differences in average rates between 3/1s and 5/1s (top line), as well as the relative quarterly default hazards of 3/1s relative to 5/1s (bottom line), evolve over (calendar) time, for each of the six origination-quarter-vintages. To reduce noise, three-quarter moving average relative default hazards are plotted, and to enhance comparability across cohorts, the relative hazard is normalized to 1 for the tenth quarter of each cohort's history.

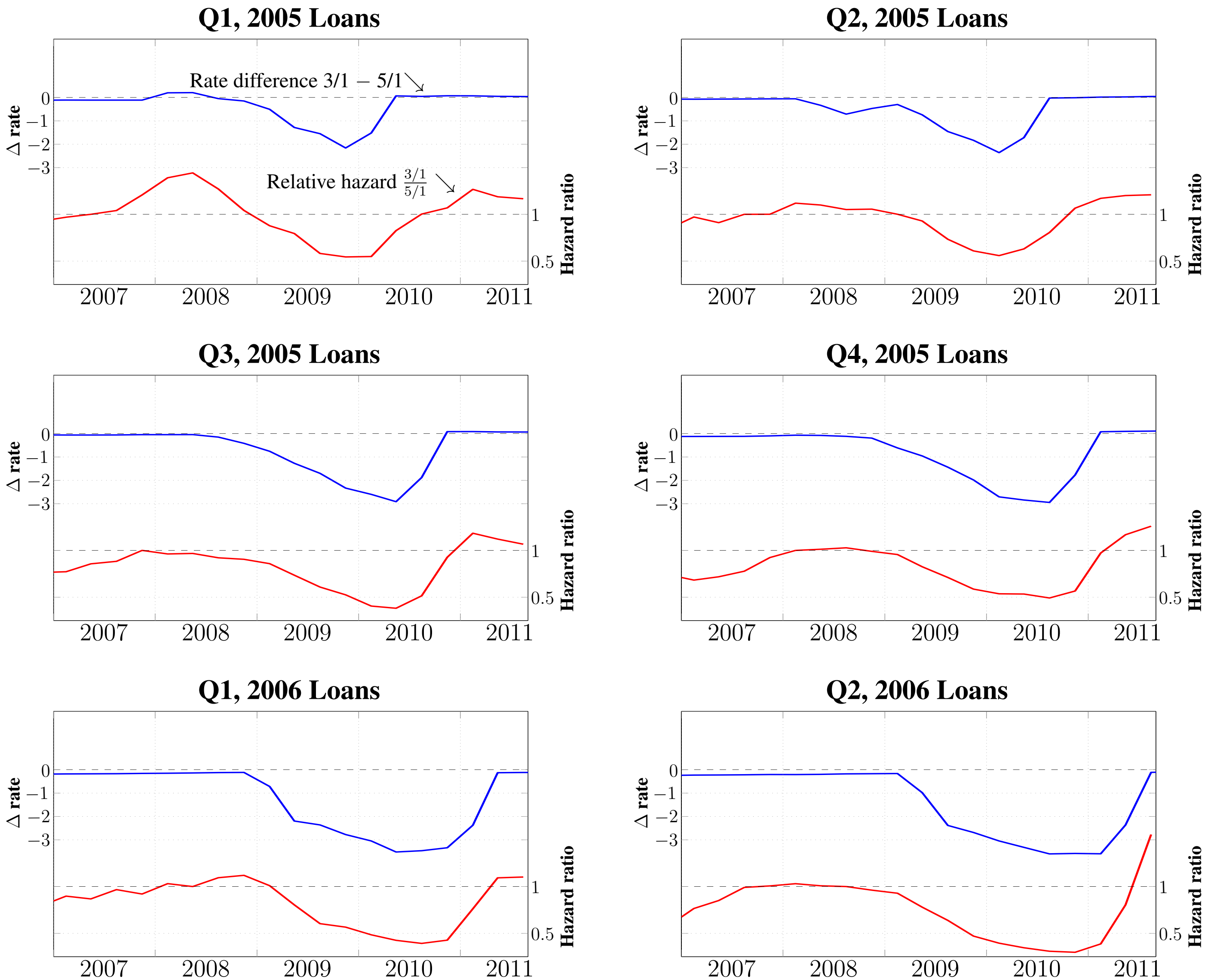


Figure A.2: Prime sample: default hazard over the life of the loan, and results of estimation

Panels are equivalents of the Alt-A sample analysis in Panels A of Figures 1 and 3 of the main paper. Coefficients and standard errors corresponding to Panel B, together with those on other control variables, are shown in Column (4) of Table A.1.

A. Default hazard over life of the loan

B. Model estimation results

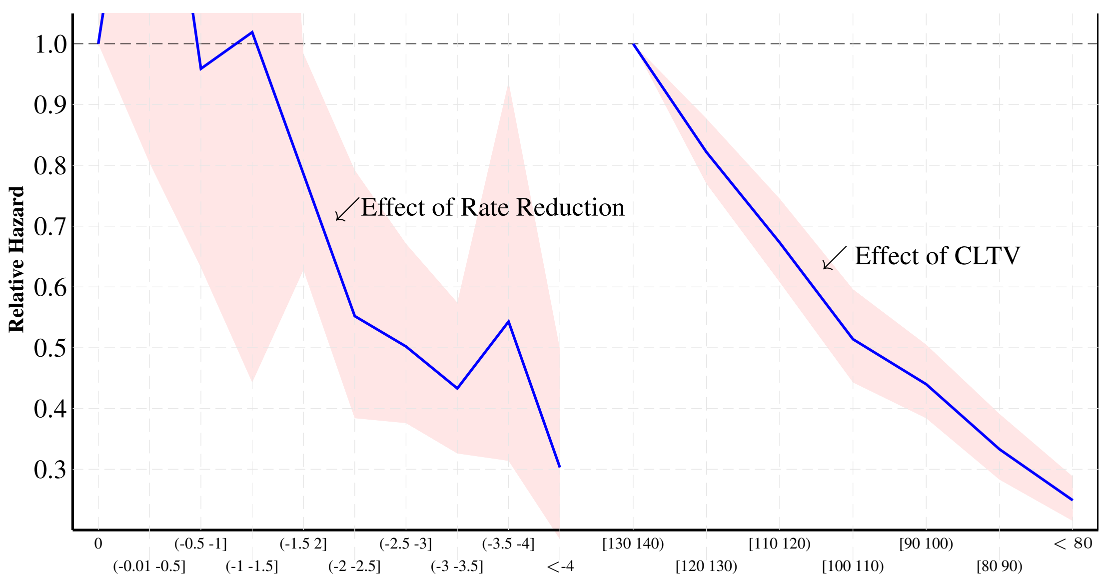


Figure A.3: Upward resets: defaults and prepayments

Panel A shows average interest rates on Alt-A 3/1 ARMs with 10-year IO feature originated in the first half of 2004. Panel B shows the default hazard and the number of defaults by loan age for these loans, normalized to month 36. Panel C shows the monthly prepayment hazard. Panel D shows the default hazard and the number of defaults by loan age for the 5/1 ARMs originated in 2005-2006:H1 (used in the main paper) relative to month 60.

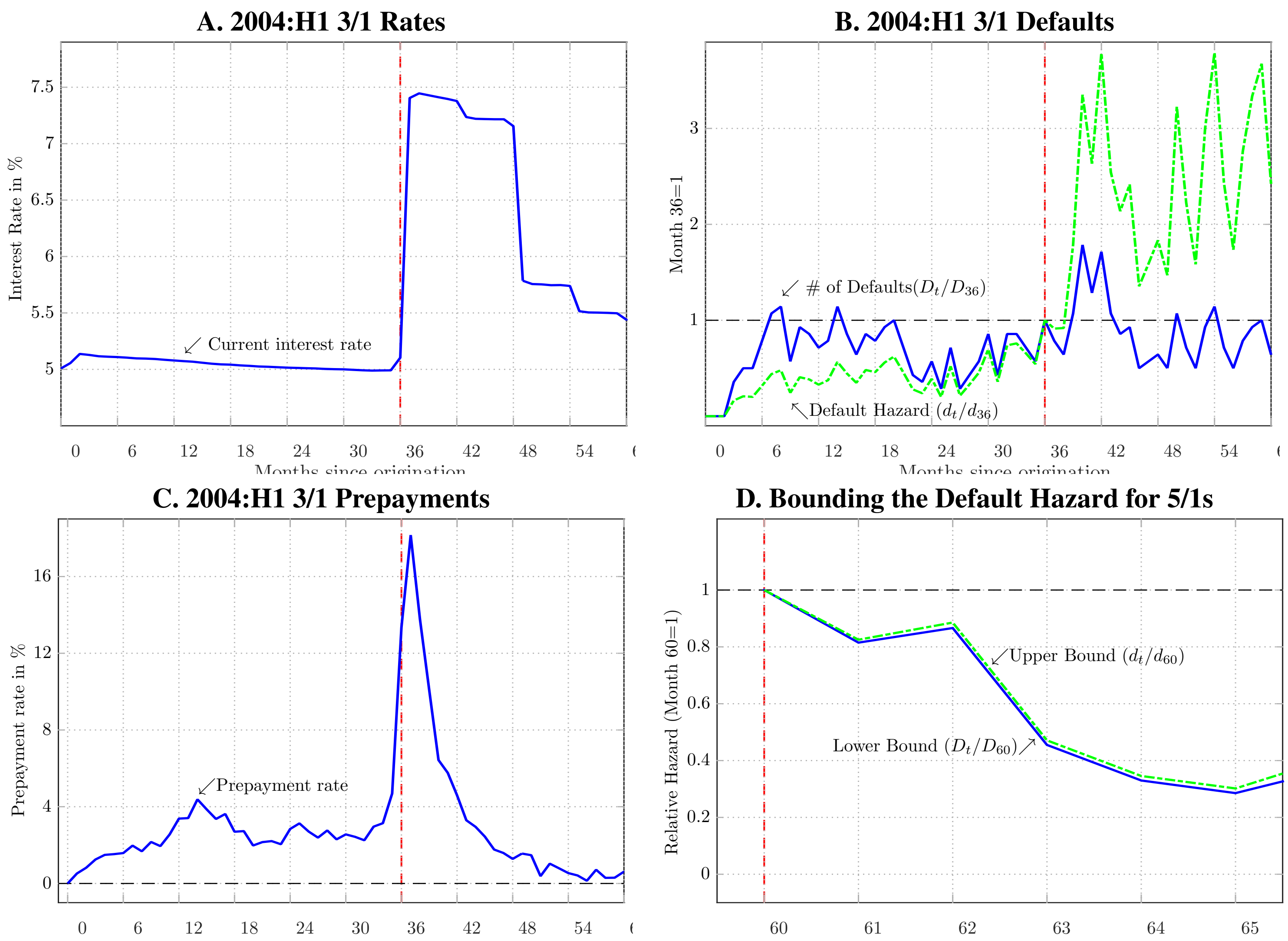


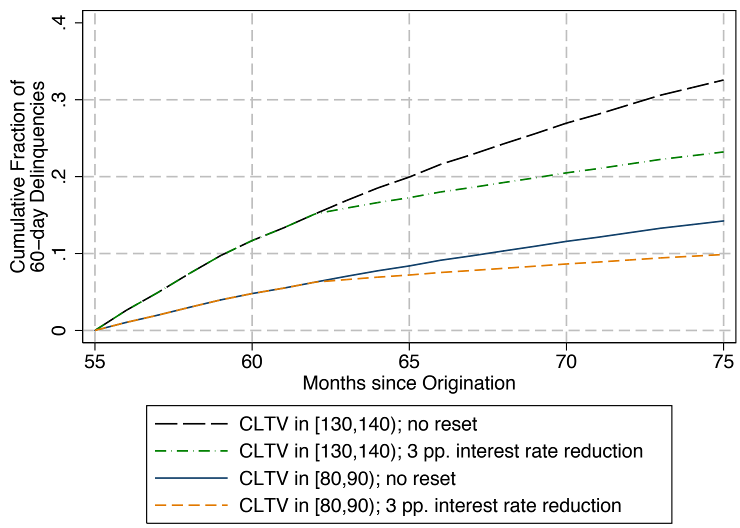
Figure A.4: Cumulative incidence of 60-day delinquency

Panel B shows the model-predicted incidence of default for a set of loans with characteristics given in Panel A, starting at loan age 55 months. Panel C shows the actual cumulative incidence of default for loans in our data with current CLTV of 130 at age 55 months. The fractions in this panel are based on loans in our sample originated up to August 2005 only, as loans originated after that are in the sample for less than 75 months.

A. Characteristics of counterfactual loans

Loan type	5/1	Documentation	Low
Initial rate	6.25%	Investor	No
FICO	720	Condo	No
Open liens	2	State	California
Loan amount	200,000	Unemployment	8% (fixed)
Original LTV	80	12-month HPA	-4%
Purpose	Purchase	FRM rate	4.50%
Ppmt penalty	No		

B. Predicted cumulative incidence of delinquency



C. Actual cumulative incidence of delinquency for loans with CLTV>130

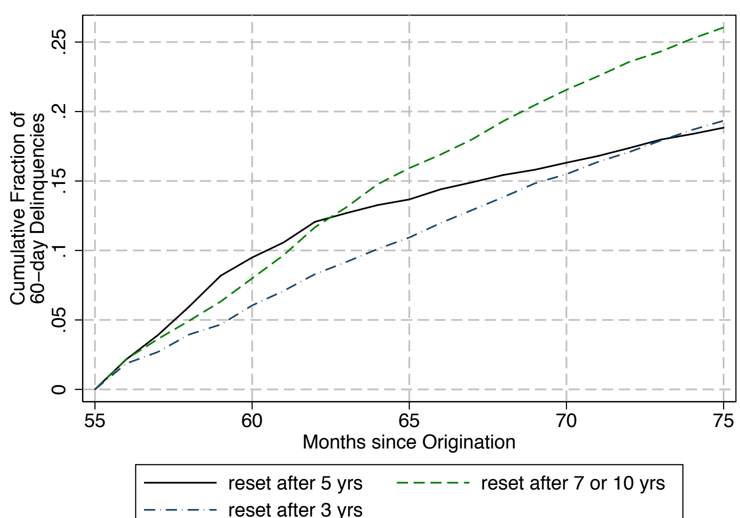
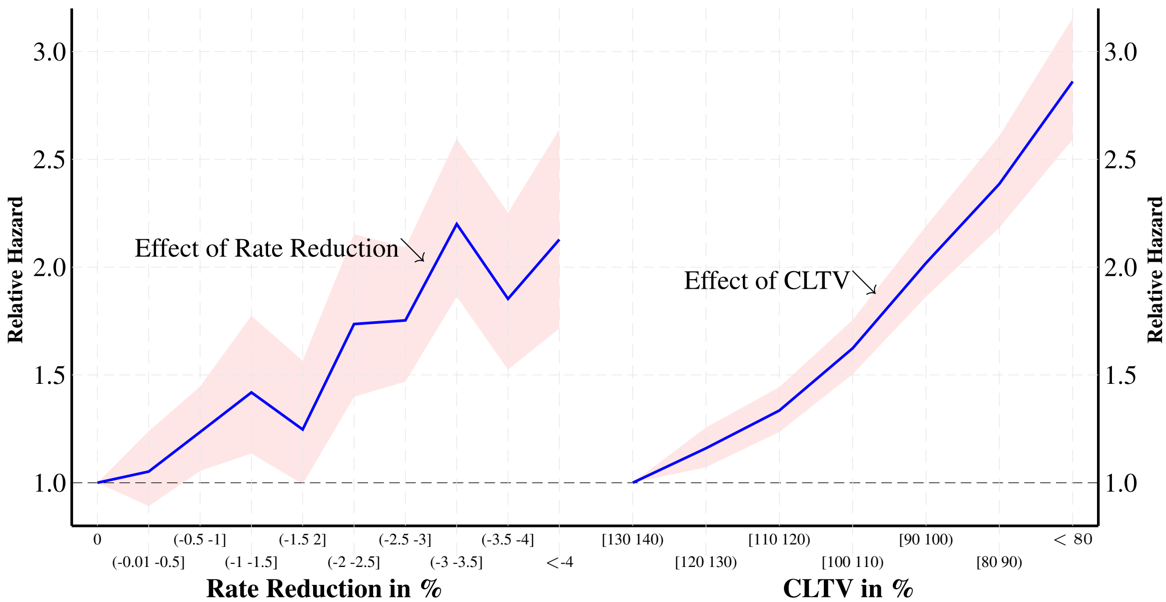


Figure A.5: Cure hazard as a function of rate reduction

Panel A displays hazard ratios for bins of interest rates (relative to mortgage rate at which borrower became 60-days delinquent) as well as combined loan-to-value (CLTV) ratios in our baseline proportional hazard regression of curing (= becoming current again or prepaying voluntarily). Coefficients and standard errors are also given in column (1) of Table A.4. Panel B shows hazard ratios and standard errors for other control variables, and provides details about the regression.

A. Effects of CLTV and rate reduction



B. Effects of control variables

SATO	1.002	Origination LTV	0.959	Not owner-occupied	0.897
	(0.035)		(0.006)		(0.024)
FICO/100	0.812	(Origination LTV)^2	1.000	Condo	0.954
	(0.019)		(0.000047)		(0.02)
Open liens = 2	0.936	Full doc.	1.209	12-month HPA	1.019
	(0.024)		(0.028)		(0.001)
Open liens ≥ 3	1.156	No doc.	1.014	Unemp. rate	0.989
	(0.057)		(0.038)		(0.007)
Log(loan amount)	0.867	Purpose = Cashout refi	1.098	6mon Δ(Unemp. rate)	1.000
	(0.018)		(0.028)		(0.010)
Prepayment penalty active	0.942	Purp. = Non-cashout refi	0.987	30-year FRM rate	1.163
	(0.023)		(0.029)		(0.108)
Loan age dummies	✓	Baseline hazard strat.	Closing q.		
State dummies	✓	Observations	847,262		
Missed interest rate bins	✓	# Loans	65,900		
Loan type × calendar q. dummies	✓	# Incidents	14,867		

Exponentiated coefficients; Standard errors (clustered at loan level) in parentheses.

Table A.1: Proportional hazard models of 60-day delinquency and prepayment

	Delinquency				Prepayment	
	(1)	(2)	(3)	(4)	(5)	(6)
Sample	Alt-A	Alt-A	Alt-A	Prime	Alt-A	Prime
Loan ages (months)	> 30	all	> 30	> 30	> 30	> 30
Interest rate − initial rate, percent (omitted bin: $[-0.01, 0.01]$):						
$(-0.01, -0.5]$	0.978	1.013	1.062	1.545	0.911	0.615
	(0.056)	(0.048)	(0.059)	(0.515)	(0.143)	(0.257)
$(-0.5, -1]$	0.836	0.831	0.878	0.959	0.864	0.990
	(0.051)	(0.053)	(0.029)	(0.204)	(0.158)	(0.416)
$(-1, -1.5]$	0.750	0.740	0.794	1.019	0.692	0.605
	(0.047)	(0.050)	(0.038)	(0.433)	(0.116)	(0.365)
$(-1.5, 2]$	0.582	0.590	0.555	0.786	0.661	0.862
	(0.062)	(0.059)	(0.042)	(0.090)	(0.150)	(0.209)
$(-2, -2.5]$	0.593	0.617	0.576	0.552	0.533	0.556
	(0.041)	(0.043)	(0.047)	(0.102)	(0.129)	(0.143)
$(-2.5, -3]$	0.436	0.455	0.454	0.502	0.421	0.415
	(0.038)	(0.043)	(0.037)	(0.074)	(0.100)	(0.110)
$(-3, -3.5]$	0.437	0.450	0.415	0.433	0.386	0.434
	(0.030)	(0.035)	(0.028)	(0.062)	(0.120)	(0.272)
$(-3.5, -4]$	0.352	0.346	0.323	0.543	0.495	0.806
	(0.048)	(0.052)	(0.043)	(0.151)	(0.124)	(0.485)
< -4	0.300	0.265	0.314	0.303	0.454	
	(0.030)	(0.027)	(0.032)	(0.077)	(0.144)	
Current CLTV (omitted bin: $[130, 140)$) :						
< 80	0.341	0.254		0.249	8.737	5.744
	(0.019)	(0.011)		(0.019)	(3.505)	(1.837)
$[80, 90)$	0.401	0.313		0.333	7.162	5.037
	(0.020)	(0.024)		(0.027)	(2.554)	(1.553)
$[90, 100)$	0.472	0.393		0.440	5.473	3.759
	(0.026)	(0.023)		(0.031)	(1.773)	(1.015)
$[100, 110)$	0.585	0.537		0.514	3.575	2.794
	(0.030)	(0.030)		(0.039)	(1.074)	(0.570)
$[110, 120)$	0.668	0.686		0.673	2.130	1.895
	(0.038)	(0.028)		(0.035)	(0.533)	(0.329)
$[120, 130)$	0.842	0.849		0.822	1.151	1.266
	(0.017)	(0.010)		(0.027)	(0.198)	(0.079)
$[140, 150)$	1.076	1.127		1.120	0.822	0.862
	(0.036)	(0.030)		(0.036)	(0.080)	(0.116)
$[150, 160)$	1.246	1.273		1.184	0.806	0.810
	(0.056)	(0.054)		(0.090)	(0.163)	(0.094)
≥ 160	1.473	1.491		1.505	1.070	0.992
	(0.056)	(0.063)		(0.112)	(0.162)	(0.095)
FICO/100	0.591	0.543		0.492	1.682	1.856
	(0.009)	(0.013)		(0.022)	(0.066)	(0.129)
SATO	1.191	1.263		1.065	1.225	0.931
	(0.046)	(0.058)		(0.101)	(0.099)	(0.124)
Open liens = 2	1.190	1.232		1.108	0.944	0.923

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	(1)	(2)	(3)	(4)	(5)	(6)
	(0.028)	(0.027)		(0.054)	(0.055)	(0.067)
Open liens = 3	0.980	0.910		1.244	1.823	1.306
	(0.054)	(0.052)		(0.123)	(0.306)	(0.173)
Ppmt. penalty active	1.065	1.065		0.632	0.542	0.543
	(0.012)	(0.011)		(0.111)	(0.040)	(0.069)
Log(loan amount)	1.062	1.189		0.965	1.331	1.241
	(0.033)	(0.039)		(0.019)	(0.067)	(0.061)
Origination LTV	1.048	1.043		1.048	0.969	1.014
	(0.007)	(0.005)		(0.009)	(0.004)	(0.007)
(Orig. LTV)^2/100	0.977	0.978		0.981	1.013	0.978
	(0.004)	(0.003)		(0.007)	(0.004)	(0.005)
Full documentation	0.600	0.596		0.701	1.387	1.090
	(0.017)	(0.015)		(0.030)	(0.041)	(0.042)
No documentation	1.087	1.085		0.802	1.021	1.171
	(0.031)	(0.018)		(0.043)	(0.049)	(0.072)
Cashout Refi	0.954	0.850		1.165	0.724	0.779
	(0.012)	(0.025)		(0.040)	(0.028)	(0.031)
Non-cashout refi	0.989	0.949		1.196	0.822	0.833
	(0.016)	(0.019)		(0.036)	(0.032)	(0.022)
Not owner-occupied	1.019	1.060		0.823	0.589	0.766
	(0.068)	(0.064)		(0.029)	(0.052)	(0.067)
Condo	0.854	0.843		0.874	0.899	0.839
	(0.037)	(0.041)		(0.063)	(0.055)	(0.054)
12-month HPA	0.985	0.983		0.983	1.015	1.011
	(0.002)	(0.002)		(0.003)	(0.006)	(0.006)
Unempl. rate (U)	1.000	1.011		1.032	0.964	0.906
	(0.006)	(0.005)		(0.008)	(0.023)	(0.036)
6-month ΔU	1.004	1.003		0.960	1.045	1.126
	(0.008)	(0.009)		(0.009)	(0.027)	(0.050)
30-year FRM rate	1.148	1.129		0.882	0.460	0.422
	(0.056)	(0.066)		(0.102)	(0.054)	(0.094)
State dummies	✓	✓		✓	✓	✓
Initial interest rate bins	✓	✓	✓	✓	✓	✓
Loan type × calendar q. dummies	✓	✓	✓	✓	✓	✓
Observations	1890615	4790556	2823245	843970	1890611	843970
# Loans	75123	138077	116866	25612	75123	25612
# Incidents	30377	55238	49914	4496	6878	5524
Log Likelihood	-267200	-499127	-470665	-34571	-58667	-44042

Exponentiated coefficients; >1 means increased hazard while <1 means decreased hazard.
Standard errors (clustered at state level) in parentheses.
In all regressions, baseline hazard allowed to vary by origination quarter.
Omitted categories: loan purpose=purchase; low documentation; owner occupied; single-family home.

Table A.2: Proportional hazard models of 60-day delinquency (Alt-A sample): Robustness and Subsamples

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Loan ages (months)	$58 - 67$	> 30	> 30	> 30	> 30	> 30	> 30
Sample restrictions	no 3/1		no 7/1+	no 3/1	no 5/1	CLTV> 140	FICO≥ 740; full doc.
Use median resets		✓					
Interest rate − initial rate, percent (omitted bin: $[-0.01, 0.01]$):							
$(-0.01, -0.5]$	0.695	1.059	0.982	0.265	0.963	0.976	0.812
	(0.728)	(0.049)	(0.049)	(0.203)	(0.054)	(0.077)	(0.475)
$(-0.5, -1]$	1.140	0.850	0.844	1.411	0.791	0.889	1.216
	(0.542)	(0.042)	(0.066)	(0.210)	(0.046)	(0.069)	(0.422)
$(-1, -1.5]$	0.476	0.873	0.771	1.049	0.692	0.664	0.990
	(0.206)	(0.069)	(0.045)	(0.251)	(0.055)	(0.037)	(0.197)
$(-1.5, 2]$	0.668	0.611	0.603	0.531	0.574	0.572	0.643
	(0.159)	(0.080)	(0.068)	(0.090)	(0.088)	(0.093)	(0.136)
$(-2, -2.5]$	0.676	0.520	0.613	0.629	0.549	0.571	0.651
	(0.083)	(0.042)	(0.053)	(0.083)	(0.060)	(0.074)	(0.183)
$(-2.5, -3]$	0.409	0.481	0.453	0.452	0.402	0.427	0.475
	(0.030)	(0.031)	(0.053)	(0.036)	(0.057)	(0.038)	(0.155)
$(-3, -3.5]$	0.440	0.422	0.465	0.430	0.449	0.409	0.582
	(0.046)	(0.027)	(0.042)	(0.039)	(0.042)	(0.024)	(0.084)
$(-3.5, -4]$	0.386	0.327	0.385	0.353	0.352	0.355	0.377
	(0.077)	(0.030)	(0.059)	(0.061)	(0.046)	(0.062)	(0.106)
< -4	0.337		0.334	0.326	0.233	0.250	0.383
	(0.048)		(0.040)	(0.039)	(0.042)	(0.037)	(0.165)
Current CLTV (omitted bin: $[130, 140)$) :							
< 80	0.445	0.341	0.359	0.343	0.317		0.195
	(0.061)	(0.019)	(0.025)	(0.018)	(0.022)		(0.051)
$[80, 90)$	0.541	0.401	0.412	0.403	0.392		0.283
	(0.062)	(0.020)	(0.026)	(0.018)	(0.027)		(0.054)
$[90, 100)$	0.558	0.472	0.507	0.476	0.417		0.296
	(0.046)	(0.026)	(0.028)	(0.023)	(0.025)		(0.041)
$[100, 110)$	0.717	0.585	0.603	0.585	0.568		0.517
	(0.041)	(0.030)	(0.040)	(0.024)	(0.027)		(0.065)
$[110, 120)$	0.710	0.667	0.715	0.667	0.606		0.600
	(0.070)	(0.038)	(0.039)	(0.034)	(0.032)		(0.055)
$[120, 130)$	0.881	0.842	0.865	0.827	0.845		0.888
	(0.042)	(0.017)	(0.029)	(0.017)	(0.015)		(0.051)
$[140, 150)$	1.075	1.076	1.058	1.062	1.134	0.693	0.970
	(0.089)	(0.036)	(0.028)	(0.039)	(0.044)	(0.016)	(0.056)
$[150, 160)$	1.163	1.246	1.237	1.222	1.307	0.815	1.298
	(0.049)	(0.056)	(0.068)	(0.052)	(0.037)	(0.012)	(0.243)
≥ 160	1.507	1.472	1.457	1.454	1.527	1	1.788
	(0.078)	(0.056)	(0.062)	(0.051)	(0.066)		(0.180)
FICO/100	0.651	0.590	0.615	0.589	0.558	0.693	0.403
	(0.031)	(0.010)	(0.014)	(0.011)	(0.012)	(0.010)	(0.034)
SATO	1.303	1.171	1.178	1.192	1.349	1.092	1.056

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	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	(0.265)	(0.042)	(0.057)	(0.055)	(0.065)	(0.085)	(0.329)
Open liens = 2	1.199	1.191	1.201	1.184	1.187	1.124	1.158
	(0.046)	(0.028)	(0.040)	(0.027)	(0.023)	(0.030)	(0.052)
Open liens = 3	0.859	0.981	1.016	0.976	0.955	0.903	0.883
	(0.104)	(0.054)	(0.071)	(0.048)	(0.074)	(0.051)	(0.103)
Ppmt. penalty active	1.213	1.065	1.024	1.084	1.085	1.043	0.861
	(0.145)	(0.013)	(0.012)	(0.018)	(0.022)	(0.015)	(0.109)
Log(loan amount)	0.855	1.061	1.118	1.058	1.013	1.033	0.883
	(0.033)	(0.032)	(0.027)	(0.036)	(0.039)	(0.020)	(0.048)
Origination LTV	1.059	1.049	1.049	1.051	1.040	1.082	1.109
	(0.013)	(0.007)	(0.009)	(0.007)	(0.007)	(0.012)	(0.027)
(Orig. LTV)^2/100	0.969	0.977	0.976	0.975	0.983	0.957	0.942
	(0.007)	(0.004)	(0.004)	(0.004)	(0.004)	(0.006)	(0.015)
Full documentation	0.712	0.601	0.581	0.598	0.643	0.660	
	(0.026)	(0.017)	(0.023)	(0.016)	(0.018)	(0.017)	
No documentation	1.099	1.089	1.062	1.085	1.171	1.106	
	(0.068)	(0.031)	(0.040)	(0.031)	(0.040)	(0.038)	
Cashout Refi	1.068	0.954	0.927	0.971	0.948	0.874	1.076
	(0.042)	(0.012)	(0.017)	(0.013)	(0.022)	(0.010)	(0.085)
Non-cashout refi	0.974	0.988	0.986	1.001	0.977	0.970	0.985
	(0.078)	(0.016)	(0.021)	(0.017)	(0.034)	(0.024)	(0.116)
Not owner-occupied	0.840	1.022	1.046	1.001	1.004	0.935	0.882
	(0.063)	(0.068)	(0.071)	(0.069)	(0.067)	(0.059)	(0.082)
Condo	0.973	0.854	0.833	0.863	0.867	0.870	0.920
	(0.041)	(0.036)	(0.037)	(0.035)	(0.045)	(0.031)	(0.058)
12-month HPA	1.001	0.985	0.984	0.985	0.986	0.990	0.979
	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.004)
Unempl. rate (U)	1.000	1.000	1.000	1.001	0.996	0.989	0.973
	(0.006)	(0.006)	(0.007)	(0.006)	(0.005)	(0.005)	(0.016)
6-month ΔU	1.036	1.004	1.004	1.007	0.998	1.001	1.066
	(0.023)	(0.008)	(0.010)	(0.009)	(0.007)	(0.011)	(0.028)
30-year FRM rate	0.621	1.148	1.283	1.103	1.020	1.041	0.981
	(0.100)	(0.054)	(0.071)	(0.074)	(0.060)	(0.068)	(0.201)
State dummies	✓	✓	✓	✓	✓	✓	✓
Initial interest rate bins	✓	✓	✓	✓	✓	✓	✓
Loan cat. × calendar q. dummies	✓	✓	✓	✓	✓	✓	✓
Observations	315482	1890615	1206985	1733461	840784	493284	232674
# Loans	34469	75123	51643	64353	34250	29541	7845
# Incidents	3152	30377	21281	27666	11807	14197	1511
Log Likelihood	-26520	-267249	-178577	-240863	-94226	-108760	-9759

Exponentiated coefficients; >1 means increased hazard while <1 means decreased hazard.
Standard errors (clustered at state level) in parentheses.
In all regressions, baseline hazard allowed to vary by origination quarter.
Omitted categories: loan purpose=purchase; low documentation; owner occupied; single-family home.

Table A.3: Summary statistics — Prime sample

A. Distribution of loan types

	3/1 ARMs		5/1 ARMs		7/1 ARMs		10/1 ARMs		Total
	#	Share (%)	#	Share (%)	#	Share (%)	#	Share (%)	#
2005H1	794	4.8	2575	15.5	714	4.3	12529	75.4	16612
2005H2	735	3.6	7219	35.1	1110	5.4	11507	55.9	20571
2006H1	345	2.0	5883	34.0	2201	12.7	8886	51.3	17315
Total	1874	3.4	15677	28.8	4025	7.4	32922	60.4	54498

B. Origination characteristics

	3/1s	5/1s	7/1s	10/1s	Total
Origination amount ($ 1000s)	386	482	510	581	541
(std. dev.)	*(282)*	*(307)*	*(353)*	*(327)*	*(326)*
LTV on first lien	74	73	73	69	71
(std. dev.)	*(11)*	*(12)*	*(13)*	*(13)*	*(13)*
CLTV (TrueLTV)	87	86	87	82	84
(std. dev.)	*(24)*	*(22)*	*(23)*	*(24)*	*(24)*
Number of liens	1.5	1.5	1.5	1.4	1.5
(std. dev.)	*(0.5)*	*(0.5)*	*(0.5)*	*(0.5)*	*(0.5)*
FICO score	735	738	742	745	743
(std. dev.)	*(45)*	*(41)*	*(43)*	*(40)*	*(41)*
Initial interest rate (%)	5.7	5.8	6.1	5.9	5.8
(std. dev.)	*(0.5)*	*(0.5)*	*(0.5)*	*(0.4)*	*(0.5)*
Margin over index rate (%)	2.2	2.5	2.3	2.5	2.5
(std. dev.)	*(0.2)*	*(0.3)*	*(0.3)*	*(0.3)*	*(0.3)*
Condo	0.26	0.24	0.23	0.16	0.19
Investor or 2nd home	0.27	0.17	0.20	0.12	0.14
Low documentation	0.25	0.41	0.28	0.45	0.42
No documentation	0.01	0.04	0.01	0.03	0.03
CA, NV, FL, or AZ	0.45	0.61	0.44	0.53	0.54
Purchase mortgage	0.56	0.60	0.60	0.55	0.57
Resets every 6 months	0.40	0.15	0.22	0.07	0.11
Prepayment penalty	0.04	0.04	0.04	0.03	0.03

C. Mean CLTV (active loans only) at different points over sample period (%)

	3/1s	5/1s	7/1s	10/1s	Total
January 2008	100	100	98	93	96
(std. dev.)	*(28)*	*(25)*	*(27)*	*(27)*	(27)
January 2010	129	126	122	113	118
(std. dev.)	*(43)*	*(40)*	*(41)*	*(38)*	(39)
November 2011	133	130	127	117	122
(std. dev.)	*(47)*	*(41)*	*(44)*	*(37)*	(40)

D. Outcomes (as of November 2011)

	3/1s	5/1s	7/1s	10/1s	Total
Goes 60+ days delinquent	0.18	0.23	0.19	0.13	0.17
Foreclosure / short sale	0.14	0.17	0.12	0.09	0.12
Voluntary prepayment	0.52	0.39	0.46	0.49	0.46
Modified at least once	0.03	0.04	0.04	0.03	0.03

Table A.4: Proportional hazard models of cures and modifications of 60+ days delinquent loans

	Cure			Modification		
	(1) All	(2) CLTV>140 only	(3) All	(4) All	(5) CLTV>140 only	(6) All
Interest rate − missed rate, percent (omitted bin: $[-0.01, 0.01]$):						
$\geq +0.01$	0.840	0.817	0.868	1.214	1.191	1.345
	(0.0836)	(0.153)	(0.0707)	(0.216)	(0.284)	(0.200)
$(-0.01, -0.5]$	1.052	1.156	0.975	1.159	1.288	1.035
	(0.0880)	(0.160)	(0.0689)	(0.200)	(0.283)	(0.158)
$(-0.5, -1]$	1.235	1.341	1.299	1.088	0.960	1.118
	(0.0993)	(0.193)	(0.0881)	(0.137)	(0.172)	(0.120)
$(-1, -1.5]$	1.419	1.709	1.343	1.164	1.132	1.048
	(0.161)	(0.309)	(0.133)	(0.173)	(0.233)	(0.141)
$(-1.5, -2]$	1.247	1.382	1.173	1.166	1.076	1.107
	(0.145)	(0.268)	(0.113)	(0.130)	(0.166)	(0.107)
$(-2, -2.5]$	1.736	1.786	1.407	1.259	1.252	1.139
	(0.191)	(0.316)	(0.134)	(0.137)	(0.178)	(0.112)
$(-2.5, -3]$	1.753	2.242	1.538	1.072	1.102	1.095
	(0.158)	(0.317)	(0.117)	(0.101)	(0.138)	(0.0901)
$(-3, -3.5]$	2.200	2.551	1.908	1.000	0.851	1.027
	(0.186)	(0.352)	(0.137)	(0.0925)	(0.110)	(0.0825)
$(-3.5, -4]$	1.853	2.084	1.640	0.898	0.901	0.904
	(0.184)	(0.339)	(0.137)	(0.0927)	(0.123)	(0.0808)
< -4	2.128	2.114	1.852	0.801	0.889	0.821
	(0.233)	(0.384)	(0.165)	(0.0948)	(0.136)	(0.0847)
Current CLTV (omitted bin: $[130, 140)$) :						
< 80	2.861			0.794		
	(0.143)			(0.0860)		
$[80, 90)$	2.386			0.878		
	(0.108)			(0.0770)		
$[90, 100)$	2.019			0.987		
	(0.0831)			(0.0650)		
$[100, 110)$	1.624			1.008		
	(0.0638)			(0.0542)		
$[110, 120)$	1.335			1.054		
	(0.0526)			(0.0500)		
$[120, 130)$	1.160			0.975		
	(0.0470)			(0.0453)		
$[140, 150)$	0.898	1.226		0.958	1.190	
	(0.0423)	(0.0576)		(0.0443)	(0.0482)	
$[150, 160)$	0.950	1.304		0.902	1.114	
	(0.0473)	(0.0610)		(0.0433)	(0.0462)	
≥ 160	0.738	1		0.835	1	
	(0.0306)			(0.0324)		
SATO	1.002	1.036		0.833	0.866	
	(0.0346)	(0.0650)		(0.0466)	(0.0665)	
FICO/100	0.812	0.749		0.815	0.819	
	(0.0194)	(0.0368)		(0.0231)	(0.0311)	

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	Cure			Modification		
	(1) All	(2) CLTV>140 only	(3) All	(4) All	(5) CLTV>140 only	(6) All
Open liens = 2	0.936	0.880		0.874	0.973	
	(0.0235)	(0.0497)		(0.0260)	(0.0435)	
Open liens $\geq$ 3	1.156	1.137		0.895	1.044	
	(0.0566)	(0.0926)		(0.0530)	(0.0802)	
Ppmt. penalty active	0.942	0.973		1.076	1.061	
	(0.0226)	(0.0679)		(0.0550)	(0.0775)	
Log(loan amount)	0.867	0.894		0.927	0.884	
	(0.0179)	(0.0455)		(0.0267)	(0.0387)	
Origination LTV	0.959	0.863		1.065	1.058	
	(0.00625)	(0.0178)		(0.0155)	(0.0300)	
(Orig. LTV)^2/100	1.026	1.101		0.963	0.968	
	(0.00483)	(0.0151)		(0.00949)	(0.0181)	
Full documentation	1.209	1.195		0.824	0.772	
	(0.0278)	(0.0576)		(0.0271)	(0.0353)	
No documentation	1.014	0.993		0.933	0.918	
	(0.0382)	(0.0997)		(0.0512)	(0.0782)	
Cashout Refi	1.098	1.280		1.082	1.215	
	(0.0277)	(0.0668)		(0.0318)	(0.0481)	
Non-cashout refi	0.987	1.075		1.109	1.108	
	(0.0294)	(0.0727)		(0.0417)	(0.0608)	
Not owner-occupied	0.897	0.999		0.436	0.426	
	(0.0239)	(0.0623)		(0.0203)	(0.0301)	
Condo	0.954	0.917		0.603	0.579	
	(0.0229)	(0.0443)		(0.0206)	(0.0265)	
12-month HPA	1.019	1.020		1.017	1.016	
	(0.00123)	(0.00304)		(0.00184)	(0.00276)	
Unempl. rate (U)	0.989	1.020		0.986	0.972	
	(0.00680)	(0.0100)		(0.00699)	(0.00839)	
6-month ΔU	1.000	1.003		1.001	1.026	
	(0.0104)	(0.0173)		(0.0131)	(0.0170)	
30-year FRM rate	1.163	0.988		1.817	2.003	
	(0.108)	(0.203)		(0.237)	(0.356)	
Age dummies	✓	✓	✓	✓	✓	✓
State dummies	✓	✓		✓	✓	
Missed interest rate bins	✓	✓	✓	✓	✓	✓
Loan type × calendar q. dummies	✓	✓	✓	✓	✓	✓
Observations	847262	424887	1354863	847262	424887	1354863
# Loans	65900	35322	106971	65900	35322	106971
# Incidents	14867	3349	23493	8649	4688	11678
Log-Likelihood	-128812.6	-26307.3	-218350.3	-70489.4	-35076.9	-103219.1

Exponentiated coefficients; > 1 means increased hazard while < 1 means decreased hazard.
Standard errors (clustered at loan level) in parentheses.
In all regressions, baseline hazard allowed to vary by origination quarter.
Omitted categories: loan purpose=purchase; low documentation; owner occupied; single-family home.