The Impact of Crisis-Period Interest Rate Declines on Distressed Borrowers *

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Abstract

We measure the causal impact of reductions in benchmark interest rates on the renegotiation and performance of distressed loans, using 2000s subprime mortgages as a laboratory. Subprime borrowers treated with larger benchmark interest rate reductions benefited from increased debt-renegotiation probabilities and lower debt-service payments. Renegotiation rates for investors were substantially higher than for baseline borrowers, suggesting that borrower financial acumen plays an important role in renegotiation outcomes. While renegotiations reduced foreclosures in the long-run, surviving treated borrowers lingered in delinquency. Findings indicate that monetary policy can reduce benchmark rates and spur debt-renegotiation but may not lead to longer-run curative outcomes.

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Crisis-period economic policy often targets distressed borrowers so as to limit broad deadweight loss to the economy and mitigate adverse distributional outcomes. In the case of monetary easing, however, distressed borrowers may experience problems of debt qualification that disrupt the refinance or debt origination channels of monetary policy (DeFusco and Mondragon, 2020).[1] Even among borrowers provided immediate interest rate relief, little is known about the longer-run salutary effects of monetary interventions. Indeed, treated distressed borrowers may suffer from subsequent performance difficulties, further damping the efficacy of policy easing.

In this paper, we provide new insights as to the short- and long-run causal impacts of crisis-period reductions in benchmark rates on distressed borrowers, using 2000s subprime adjustable-rate mortgages (ARMs). During their adjustable-rate period, subprime ARMs typically featured an interest rate benchmarked to Libor that adjusted every 6 months. Thus, once the interest rate was set for a 6-month period, the Libor value used to calculate the mortgage rate often differed substantially from subsequent market rates, making these loans act as fixed-rate instruments during that 6-month window. As markets and Libor were quite volatile following the onset of the Great Recession, such mortgage contract rigidities meant that calculated subprime ARM mortgage rates often did not reflect prevailing financial conditions, potentially impeding the pass-through of monetary policy to distressed borrowers who often did not qualify for debt refinance (DeFusco and Mondragon, 2020; Amromin et al., 2020).

Exploiting variation in loan contract terms along with aggregate volatility in Libor, we first uncover and evaluate a debt-renegotiation channel of monetary policy, whereby reductions in benchmark interest rates induce loan modifications.[2] Lower benchmark rates reduce lender funding costs so as to bolster lending margins post-modification.[3] Rate declines then tilt lender

[1]Other factor may also limit monetary transmission. See Calza et al. (2013), Scharfstein and Sunderam (2016), Beraja et al. (2018), Agarwal et al. (2018), Gerardi et al. (2020), Agarwal et al. (2020), and Amromin et al. (2020).

[2]Typically, debt-renegotiation is not considered as part of the monetary policy transmission mechanism. As noted in their review of the refinancing channel of monetary policy, Amromin et al. (2020) note: "As a practical matter, lenders are generally reluctant to refinance delinquent mortgages, making loan modification the only possible avenue for transmission of stimulus measures. However, since modifications are driven primarily by lender willingness to restructure non-performing debt and by government incentives, as opposed to monetary policy actions per se, we leave them out of the present discussion."

[3]Various frictions can impede debt-renegotiations. See Piskorski et al. (2010), Agarwal et al. (2011), Adelino et al. (2013), Agarwal et al. (2017), and Kruger (2018). If lenders are sufficiently hedged against borrower default, they become less inclined to renegotiate debt (the "empty creditor problem"). See Bolton and Oehmke (2011)

incentives toward loan modification, relative to the substantial losses incurred by lenders in the case of loan nonperformance and default. Likewise, declines in benchmark interest rates increase incentives for borrowers to pursue renegotiation, as modifications stemming from larger rate declines may result in lower monthly payments. We then exploit a natural experimental opportunity via the above interest rate modification channel to plausibly assign different benchmark interest rates to distressed adjustable-rate loans. Our aim here is to examine the debt-renegotiation-induced short- and long-term impacts of benchmark rate adjustments on borrower outcomes.

We find that reductions in benchmark interest rates during the 2000s crisis resulted in marked increases in debt-renegotiation probabilities. A one percentage point drop in 6-month Libor (the typical interest rate index for 2000s subprime ARMs) during the Great Recession increased the probability of a subprime mortgage interest rate modification by 5.46 percentage points (robust S.E. = 0.30%; t-statistic = 18.23). Given that the overall modification rate for subprime ARMs was 8.6%, an estimate of 5.46 percentage points is substantial. Moreover, benchmark interest rate declines translated into meaningful reductions in debt-service payments: Libor change-induced debt-renegotiations lowered monthly mortgage interest rate payments by 0.296 log points (robust S.E. = 0.011; t-statistic = 26.89), or, correspondingly, by $480 on average per borrower per month. This decline in mortgage payments also reduced total debt payments relative to income (back-end debt-to-income (DTI) ratios) for modified borrowers, coinciding with a broader easing of their debt-service obligations relative to income.

While these results extend to current borrowers, borrowers in default, and across geographies, modification probabilities were 50 percent higher for real estate investors or plausibly more experienced borrowers. Compared to baseline owner-occupied borrowers, real estate investors (non-owner-occupied borrowers) and more experienced borrowers (those whose loans were secured by a second home) were likely less susceptible to sub-optimal mortgage decisions (List, 2003), more aware of modification opportunities, and more adept at navigating the renegotiation process. As such, our results suggest that borrowers' investment experience and

and Danis (2017).

financial acumen are critical to renegotiation and modification outcomes.

Over the medium- and longer-term, the modifications induced by Libor declines led to markedly lower foreclosure rates for treated borrowers: After 48 months, the probability that a borrower loses their home to an REO foreclosure or forced sale with a loss to the loan investor fell by 41.6 percentage points (robust S.E. 6.26%, t-statistic = 6.63).[4] However, among surviving loans, borrowers that received benchmark rate change-induced modifications were adversely selected: They were less likely to be current in loan payment and more likely to linger in late-stage delinquency. Indeed, a loan-level regression of an indicator variable for if a loan entered REO foreclosure, was liquidated with a loss, or was 90 or more days delinquent after 48 months on Libor changes yields nearly a precisely estimated coefficient of zero (estimate = 0.09%; robust S.E. = 0.35%). This finding highlights the longer-run limits of interest rate declines in alleviating borrower distress in the wake of an economic crisis.

Untangling the causal effects of reductions in benchmark rates on distressed borrowers during a crisis is complicated by several factors. First, monetary easing is an aggregate phenomenon, in the sense that all economic agents are concurrently exposed to lower benchmark Libor rates. Hence, the creation of treatment and control groups for otherwise comparable borrowers is difficult. Moreover, declines in benchmark interest rates and economic distress often occur contemporaneously. Prevailing economic conditions are thus a confounding factor in any assessment of declining interest rates, debt renegotiation, and subsequent borrower outcomes. Debt-renegotiation and restructuring are also typically low-frequency or one-off events, while interest rate changes can be frequent. This mismatch in data frequency may obfuscate the causal relationship between benchmark interest rate declines and debt-restructuring.[5]

To overcome these challenges, our identification strategy exploits a natural experimental opportunity that combines ex-ante differences in mortgage contract terms with the aggregate

[4]COVID-19-induced interest rate declines are also correlated with lower bankruptcy rates, consistent with our findings: "Zombies Are on the March in Post-Covid Markets." *Bloomberg News*. June 14, 2021.

[5]In the housing literature, researchers have typically examined the relationship between legislative actions and debt-renegotiations (Mayer et al., 2014; Agarwal et al., 2017, 2020; Ganong and Noel, 2020; Gabriel et al., 2020), or securitization and renegotiation (Maturana, 2017; Kruger, 2018), or mortgage market design more broadly (Piskorski and Seru, 2018). The impacts of debt-renegotiation also extend to consumer debt (Auclert et al., 2019). In contrast, papers considering interest rate changes typically examine their impacts on mortgage refinancing (Beraja et al., 2018) or household consumption (Di Maggio et al., 2017).

volatility in 6-month Libor (the typical interest rate index for 2000s subprime ARMs). Together, these factors allow us to simultaneously assess the debt-renegotiation channel of monetary policy and the quasi-random assignment of different benchmark interest rate changes to otherwise similar borrowers via the loan modification mechanism. First, note that the ARMs originated during the 2000s typically featured an initial fixed-rate period followed by an interest rate adjustment (or "reset"). The new interest rate was equal to a benchmark interest rate (e.g., Libor) plus a margin.[6] A key feature of these adjustments is that mortgage servicers typically measured the benchmark interest rate several days before adjustment so that the mortgage servicer could notify the borrower in advance of the new monthly payment, the so-called "look-back period." Thus, in the lead-up to an ARM payment change, the benchmark interest rate (e.g., Libor) is first measured. The servicer then notifies the borrower about the upcoming payment adjustment, and finally, the borrower's payment changes. Interest rate measurement typically occurs 15 - 45 days before the payment adjustment. Gupta (2019) notes that lookback periods differ across loans and finds that their variation is uncorrelated with ex-ante borrower characteristics. He uses lookback periods to account for variation in realized mortgage rates for current borrowers and assesses the impact of mortgage rate differences on the contagion of foreclosure starts following first adjustment. We build on Gupta's approach by also using lookback periods as part of our identification scheme.[7] In this paper, however, we assess how changes in benchmark interest rates directly affect debt renegotiation for distressed loans and how Libor change-induced modifications impact borrower outcomes. Broadly, our analysis centers on the policy-relevant mechanisms of interest rate transmission via the debt-renegotiation channel and the longer-term performance of borrowers who are assigned lower interest rates via modifications.

Specifically, we first document that subprime ARMs originated during the 2000s follow a specific loan archetype: Nearly 75% were indexed to 6-month Libor with a mortgage payment that adjusted every 6 months during the variable rate period.[8] Accordingly, we employ a

[6] 2000s ARMs were also often subject to rate caps and floors at each adjustment and over the life of the loan.

[7] See also Gupta and Hansman (2022).

[8] Another 10% of subprime ARMs also had a 6 month payment adjustment frequency and were indexed

sample of subprime ARMs indexed to 6-month Libor before their first payment adjustment. Using loan contract terms and aggregate Libor interest rates, for each ARM we compute the change in 6-month Libor between the first benchmark interest rate measurement date (first measurement) and the first payment adjustment date (first adjustment). Our assignment of different benchmark interest rate changes to different borrowers is thus based on the 6-month Libor change between first measurement and first adjustment (henceforth, the loan-level Libor change). In our regressions, we control for the lookback period in days, akin to a linear time trend. Thus, variation in our assignment of different benchmark interest rates to different borrowers stems from non-linear Libor changes between first measurement and first adjustment.

With loan-level differences in the change in Libor in hand, we pursue an instrumental variable (IV) two-stage least squares (2SLS) research design. In the first stage, we regress the loan-level probability of an interest rate modification between first measurement and first adjustment (an indicator variable) on loan-level Libor changes. For this relationship to be causal, loan-level Libor changes must be as good as randomly assigned across borrowers (the IV independence assumption). Congruent with the independence assumption, balance tests show that first measurement to first adjustment Libor changes are uncorrelated with origination and pre-first measurement borrower characteristics. Likewise, in falsification tests, we similarly find that Libor changes do not predict mortgage and credit performance outcomes one year before first measurement.

Under the independence assumption, results from our first stage regressions show that a decline in Libor causes an increase in the probability of subprime ARM modification. Figure 1, panel A visualizes this first stage relationship by plotting the mean probability of an interest rate modification by first payment adjustment year-quarter (using no control variables). We plot the first and fourth quartiles of subprime ARMs sorted by their Libor changes between first measurement and first adjustment. The plot documents that loans treated with a larger Libor decline (1st quartile, blue line) experienced substantially higher average modification probabilities than those treated with relatively smaller Libor declines (e.g., 4th quartile, red

to Libor, but the exact Libor term was not identified in the data. Yet these loans were also likely indexed to 6-month Libor. Therefore, nearly 85% of 2000s subprime ARMs likely were indexed to 6-month Libor.

line). Indeed, moving from the fourth to first Libor change quartile (red line to blue line) corresponds to an increase in the probability of modification of nearly 2 percentage points in 2008Q1 and over 10 percentage points in 2009Q1. As noted above, in our preferred first stage regression with controls, a one percentage point reduction in Libor causes the probability of modification to increase by 5.46 percentage points (t-statistic = 18.23).

Figure 1, panel B plots reduced form estimates that document the causal transmission of Libor declines to average mortgage payments for the entire sample of subprime ARMs. Importantly, the first-to-fourth quartile Libor differential pattern in mortgage payments (panel B) mirrors the same Libor differential pattern in the probability of modification (panel A). Thus, these reduced form estimates show that subprime borrowers treated with larger Libor declines experienced lower average mortgage payments.

In the second stage, our 2SLS estimates capture the causal impact of Libor change-induced modifications on borrower-level outcomes. For our 2SLS approach to be causal, we require that Libor changes only affect borrower level outcomes through modifications (the IV exclusion restriction). In our case, the exclusion restriction would be violated if Libor changes between first measurement and first adjustment affect borrower outcomes through channels outside of the modification mechanism (outside of the first stage relationship). Indeed, changes in benchmark interest rates, such as Libor, likely affect interest payments on other debts and borrowers' financial asset values. Thus to account for broader interest rate changes, all of our regression models include first adjustment date fixed effects. We therefore only compare borrowers within the same first adjustment month who face the same benchmark interest rates over time. This leaves modifications as the only channel through which Libor changes between first measurement and first adjustment can impact borrower level outcomes, consistent with the exclusion restriction.

The last threat to identification centers on the IV monotonicity (no defiers) assumption. In our setup, the monotonicity assumption maintains that Libor declines between first measurement and first adjustment will not decrease the probability of modification. During normal economic times not characterized by widespread default and foreclosure, this assumption may

not hold. Indeed, a mortgage investor in the subprime PLS securities market might be reluctant to modify a loan in the wake of a decline in Libor between first measurement and first adjustment as a higher spread to prevailing market rates would translate into additional investor profits. However, the 2000s housing crisis witnessed substantial house price declines and high foreclosure rates among distressed, subprime ARM borrowers, with attendant deadweight losses for both borrowers and lenders. Therefore, lenders had an incentive to modify subprime ARMs to avoid default and related loss recognition. In robustness checks, we examine subgroups of potential defiers.[9] For all of these subgroups, Libor declines between first measurement and first adjustment increase the probability of modification, congruent with the monotonicity assumption. Moreover, in an additional check, we remove likely defiers, current loans four months before first adjustment. The estimates from this check match our main results. Together, these findings imply defiers are not present in our data and that the monotonicity assumption is likely to hold.

Overall, our 2SLS estimates indicate that Libor change-induced subprime loan modifications lower debt-service payments (monthly mortgage payments) and reduce foreclosure likelihood. Yet among surviving loans, borrowers treated with Libor change-induced modifications were less likely to be current and were more likely to linger in late-stage delinquency. These results persist up to four years after first payment adjustment. Overall, our findings highlight the potential longer-term limits of monetary accommodation and related interest rate reductions in aiding distressed borrowers in the aftermath of a crisis. Indeed, lower interest rates and widespread loan modification among distressed borrowers may not lead to longer-run curative outcomes as intended by monetary easing. While policy interventions and related loan modifications appear successful in the immediate term in keeping distressed borrowers in their homes, they often coincide with ongoing salient performance difficulties among treated borrowers.[10]

[9]These subgroups include borrowers current four months before first adjustment, borrowers in non-sand states, and non-subprime, current borrowers whose homes were in zip codes that experienced positive house price growth from 2006M01 - 2008M07.

[10]Our results also link the broader monetary policy transmission and housing literatures. Haughwout et al. (2016), Agarwal et al. (2017), Agarwal et al. (2020), and Gabriel et al. (2020) examine the impact of debt-renegotiations on distressed borrowers and other housing-related outcomes. Finally, an extensive literature examines the transmission of interest declines or monetary policy to housing markets and the broader economy. See Amromin et al. (2020) for an overview. One such study related to our work is Fuster and Willen (2017), who

Finally, our results have important implications for mortgage market design. For example, a widely held view contends that adjustable-rate mortgages, relative to fixed-rate mortgages, may be advantageous as ARM payments adjust downwards during a crisis.[11] In line with this position, our results suggest that ARM borrowers treated with lower benchmark rates are less likely to lose their homes to an REO foreclosure or forced sale. However, our results also indicate that these same treated borrowers are subsequently more likely to re-enter and linger in serious delinquency, limiting the crisis-era benefits of ARM mortgages for lower quality borrowers.

1 Data Sources

Our primary loan-level dataset comprises the universe of subprime ARM loans sold into private-label securitization (PLS) from Moody's Blackbox. These data cover a multitude of loan-level mortgage origination and performance characteristics. We merge these data with the Equifax consumer credit panel to obtain, for example, the borrower's credit score and estimated debt-to-income before first payment adjustment. For our main econometric analysis, we retain loans with an origination date between 2002M01 and 2006M12 and a first payment adjustment date (the year-month where the mortgage payment adjusts following an interest rate reset) between 2007M10 and 2009M09. Our primary dataset also includes loans at any stage of delinquency four months before first adjustment. Yet it does not include loans paid off, entered into REO foreclosure, or liquidated with a loss in the month before first adjustment.

To assess the regional impacts of aggregate interest rate declines, we also obtain zip code house price indices from Zillow and zip code household income from the IRS Statistics of Income. Lastly, Libor interest rates are from the Federal Reserve Economic Database (FRED), and fed funds futures are from Bloomberg.

use the post-Global Financial Crisis period of low interest rates to assess the default impacts of low mortgage payments on borrowers facing negative equity. Fuster and Willen (2017) find that lower payments reduce defaults for these borrowers.

[11] See for example Fuster and Willen (2017), Piskorski and Seru (2018), and Amromin et al. (2020).

2 2000s Subprime ARMs: Benchmark Interest Rate Indices and Payment Adjustment Frequencies

Table 1 presents counts and summary statistics that describe the ARMs sold into PLS during the 2000s housing boom, where panel A focuses on subprime loans (FICO credit score ≤ 660), and panel B presents summary statistics for non-subprime ARMs (FICO credit score > 660). We tabulate summary statistics for ARMs by the benchmark interest rate index (columns (1) and (2)) and the payment adjustment frequency (column (3)). Each panel only shows the top 5 categories in terms of loan counts.

Typically, the interest rate and the mortgage payment associated with an ARM adjust at regular intervals. The new mortgage rate at adjustment is usually equal to a benchmark interest rate (e.g., Libor) plus an additional margin.[12] Panel A documents that the vast majority of 2000s subprime ARMs were indexed to Libor (over 86%), with over 74% of these loans indexed to 6-month Libor with a mortgage payment that adjusts (e.g., due to an interest rate reset) every 6 months (panel A, row 1). Another 10% of subprime ARMs with a 6 month payment adjustment frequency (panel A, row 2) also tracked Libor, but with the exact term of the Libor interest rate not identified in the data. Yet as the mortgage interest rates for these ARMs adjust every 6 months (row 2, column 3), a large portion of these loans were also likely benchmarked to 6-month Libor. Together, these facts indicate that the subprime ARMs originated and sold into PLS during the 2000s boom follow a specific loan archetype: They were typically benchmarked to 6-month Libor with a mortgage interest rate that adjusts every 6 months. Thus, our analysis below focuses on these subprime ARMs as they constituted a substantial share of distressed mortgage debt during the 2000s housing crisis.

Table 1 also examines key origination summary statistics and the share of loans that experienced their first payment adjustment in each monetary policy episode during the 2000s housing bust. Columns (6) and (7) of table 1, panel A show that subprime Libor indexed ARMs with a 6 month payment adjustment frequency (rows 1 and 2) were risky. Indeed, based on origination

[12] Interest rate changes can also be subject to caps and floors at each payment adjustment or over the life of the loan.

average FICO and LTV, subprime ARMs benchmarked to 6-month Libor with a 6 month payment adjustment frequency represent the riskiest group of 2000s PLS ARMs in table 1. Their average origination FICO credit score is under 600, and their mean origination LTV is over 81.

Next, columns 8-11 in table 1 show when the share of loans within each row experienced their first payment adjustment by monetary policy episode (e.g., pre-fed funds easing (column 8), the fed funds easing period (column 9), QE1 (column 10), and the post-QE1 period (column 11)). Thus, columns (8) - (11) by row sum to 100%. Nearly 30% of subprime ARMs indexed to 6-month Libor with a 6-month payment adjustment frequency (row 1 of panel A) experienced their first payment adjustment before the initial fed funds easing cycle (e.g., before 2007M10). An additional 46% first entered their first payment adjustment period during the traditional fed funds easing cycle (200710 to 2008M11). Thus, by the start of QE1 in November 2008, over 75% of these subprime ARMs experienced floating interest rates, meaning that monetary easing and broader interest rate declines could potentially have a marked impact on these loans. It's the causal effects of such interest rate declines, induced in part by monetary easing, on subprime ARM borrowers that we aim to uncover below.

Finally, for comparison, table 1, panel B shows the same counts and summary statistics for the top 5 non-subprime ARM categories also by interest rate index and first payment adjustment date. A notable share of non-subprime ARMs were indexed to 6-month Libor with a 6 month payment adjustment frequency (33% from panel B, row 1, column 5). Yet non-subprime loans were substantially less concentrated in a specific interest rate index or payment adjustment frequency group. Thus, non-subprime ARMs were dispersed across benchmark indices and payment adjustment frequency groups, whereas, as noted above, subprime ARMs originated during the 2000s boom follow a specific loan archetype.

3 Preliminary Evidence: Libor Changes, Subprime ARM Mortgage Rates, and Modifications

Figure 2 describes the path of 6-month Libor (panel 1A) and the impact of monetary policy on Libor (panel 1B). The figure also plots expected subprime ARM rates and payments based

on origination loan contract terms and 6-month Libor versus the corresponding realized values (panels 2A, 2B, and 3A). Finally, panel 3B shows subprime ARM modifications rates throughout the 2000s housing bust and the subsequent period of declining interest rates and monetary easing.

First, figure 2, panel 1A provides an overview of the path of benchmark interest rates from the start of the subprime bust in 2007 through the early QE period. Specifically, the graph plots the expected fed funds rate in 6 months as measured by fed funds futures (blue line) along with 6-month Libor (red line). We consider 6-month Libor as most subprime ARMs tracked 6-month Libor during their adjustable-rate period (table 1). Also, our identification strategy exploits the volatility in 6-month Libor, along with different interest rate measurement dates for ARMs with the same first adjustment date, to assign different benchmark interest rate changes to otherwise similar borrowers.

Panel 1A shows that while the expected fed funds rate and 6-month Libor follow the same general downward trend, 6-month Libor experienced relatively large bouts of volatility, especially in late 2008 and early 2009. Due to ex-ante differences in interest rate measurement dates for otherwise comparable loans, these large swings in 6-month Libor create differences in Libor changes between borrowers' first interest rate measurement and first payment adjustment. This thus yields the quasi-random assignment of different benchmark interest rate changes across borrowers. Indeed, through mid-2007, the spread between 6-month Libor and the expected fed funds rate was narrow as credit conditions had yet to tighten. Then, with the onset of the Great Recession and housing crisis-induced financial market distress, the expected fed funds rate fell sharply. In contrast, 6-month Libor became volatile and remained elevated. The 6-month Libor–expected fed funds rate spread thus widened, signaling a broader deterioration in credit conditions. Then at the end of 2007, 6-month Libor fell quickly, but its spread relative to the expected fed funds rate persisted. In mid-2008, both the expected fed funds rate and 6-month Libor increased somewhat before the Lehman Brothers crisis in September 2008, where Libor spiked. In late-2008, Libor fell rapidly before increasing again slightly in early 2009. At that point, the expected fed funds rate had neared its zero lower bound, and Libor began a gradual

downward trend that proceeded through 2010.

Panel 1B documents the impact of monetary policy shocks on 6-month Libor during both the conventional (red line) and QE (blue line) periods. To measure the Libor response to conventional monetary policy actions, we calculate the difference in 6-month Libor from the day before to the day after each FOMC meeting (Vissing Jorgensen and Krishnamurthy, 2011). We then cumulatively sum these changes from January 2007 to October 2008 to get the total impact of conventional monetary policy shocks on 6-month Libor. The red line in panel 1B indicates that conventional monetary policy shocks had a sizable effect on 6-month Libor, leading to a one percentage point decline from mid-2007 to early 2008. During the latter half of 2008, conventional monetary policy shocks were contractionary, and 6-month Libor increased 60 basis points in response to these shocks. The blue line in panel 1B similarly computes the impact of unconventional monetary policy shocks on 6-month Libor. QE dates are from (Greenlaw et al., 2018, (GHHW)).[13] The blue line in panel 1B shows that unconventional monetary policy shocks lowered 6-month Libor by over 100 basis points.[14]

Next, figure 2, panel 2A documents that large mean differences can arise between actual 2000s subprime ARM interest rates versus those predicted by origination loan contract terms and 6-month Libor realizations. This observation implies that interest rate modifications were prevalent during this period. In particular, panel 2A focuses on subprime ARMs indexed to 6-month Libor with a 6 month payment adjustment frequency (e.g., table 1, row 1), whose first adjustment occurred in January 2009 (e.g., the first time that their payment adjusts following the initial fixed-rate period). The plot shows the predicted (blue-dashed line) versus the actual (red-solid line) credit risk-adjusted mean ARM interest rate. The predicted interest rate represents the estimated mean interest rate that would have prevailed had no borrowers received a mortgage modification. The plotted credit risk-adjusted mortgage interest rates account for origination loan-level differences: They correspond to a borrower with a FICO

[13]Using the GHHW QE dates, we measure the impact of monetary policy shocks on 6-month Libor during the zero-lower bound period by cumulatively summing the difference in 6-month Libor from the day before to the day after each monetary policy date, as during the conventional monetary policy episode.

[14]For an overview of unconventional monetary policy in response to the Great Recession, see Borio and Zabai (2018).

credit score of 600, an LTV of 82, an ARM interest rate margin of 6%, and the sample mean origination balance and initial interest rate. More specifically, the credit-risk-adjusted interest rates are the estimates of year-month fixed effects from the following regression (without an intercept), estimated separately for the actual and predicted mortgage interest rates:

$$\begin{aligned} \text{Interest Rate}_{it} = \tau_t &+ \beta_1(\text{FICO}_i - 600) + \beta_2(\text{LTV}_i - 82) \\ &+ \beta_3(\text{Margin}_i - 6\%) + \beta_4(\text{OrigBal}_i - \text{OrigBal}_{\text{mean}}) \\ &+ \beta_5(\text{Initial Rate}_i - \text{Initial Rate}_{\text{mean}}) + \varepsilon_{it} \end{aligned} \tag{1}$$

Figure 2, panel 2 reports the fixed effect estimates ($\hat{\tau}_t$) from equation 1. Panel 2A plots the fixed effect estimates when predicted (blue-dashed) or actual (red-solid) mortgage interest rates represent the outcome variable. Panel 2B shows the output from similar regressions but where monthly predicted and actual interest rate payments represent the dependent variables. The blue-dashed line in panel 2A documents that the ex-ante expected mean mortgage rate would have increased from just under 8.5% to just over 9% in January 2009 with the first payment adjustment. Panel 2B shows that the corresponding increase in interest rate payments (not including principal payments) using the predicted interest rate would have been $140 on average per month (a nearly 10% increase). However, the red-solid lines in panels 2A and 2B also highlight that mean actual interest rates and interest rate payments fell dramatically with the start of the variable interest period. The large mean differences between actual and predicted mortgage rates imply that several borrowers with a first adjustment date in January 2009 received a modification. These modifications led to an economically meaningful decline in debt-service payments.

Such disparities, those between predicted and actual interest rates following the initial reset, extend across first adjustment date cohorts. In figure 2, panel 3A, we plot the credit risk-adjusted mean difference in the actual and predicted subprime ARM interest rates for 6 quarters after first adjustment by first adjustment year-quarter from 2007Q4 through 2009Q3. Darker lines indicate an earlier year-quarter of first adjustment. As in panel 2, the mean differences between the actual and predicted subprime ARM mortgage interest rates are credit risk-adjusted using the regression in equation 1 by each first adjustment date. The graph shows

that across all of the plotted first adjustment year-quarters, there are considerable differences between the actual and predicted mortgage rates. Once ARMs near first adjustment, the mean actual interest rate falls relative to the rate expected from loan contract terms. The differences between the actual and predicted interest rates are large with a range of 1–1.6 percentage points. Therefore, several 2000s subprime borrowers received an interest rate modification during the housing crisis and experienced a decline in interest rate payments. Indeed, panel 3B indicates that subprime borrower modification rates are highly (inversely) correlated with these interest rate reductions, where the modification rate reached over 30% for borrowers in later first adjustment cohorts.[15]

Overall, figure 2 shows that the large ARM interest rate reductions relative to predicted interest rates, along with high modification rates, are broadly correlated with a period of falling benchmark interest rates. Yet this preliminary evidence alone cannot ascribe the subprime ARM interest rate modifications to broader interest rate declines. Indeed, benchmark interest rates were falling due to widespread economic and financial market distress, induced at least in part by struggling subprime borrowers that may have been targeted for modification. Thus, any naive associations between falling benchmark interest rates and subprime interest rate modifications are likely contaminated by the broader economic and mortgage market performance. Therefore, in the next section, we outline our instrumental variable identification strategy to generate causal estimates of the impacts of Libor change-induced modifications on borrower level outcomes.

4 Instrumental Variable Identification Strategy

A key feature of subprime PLS ARM loans is that they typically contain an initial fixed-rate period followed by a subsequent interest rate adjustment. After adjustment, the new interest rate is equal to a benchmark interest rate (e.g., Libor), plus an additional margin.[16] To allow mortgage borrowers to prepare for mortgage interest rate and mortgage payment changes,

[15] Panel 3B treats modification as an absorbing state. Thus, once a loan is modified, it is treated as modified through the entire sample. Panel 3B thus reports for each date, the share of loans that were ever modified grouped by first adjustment year-quarter.

[16] 2000s ARMs were also often subject to rate caps and floors at each adjustment and over the life of the loan.

mortgage loan contract terms typically specify that servicers must first measure the interest rate index several days before payment adjustment. This so-called "lookback period," which is often between 15 and 45 days, varies across loans and can lead to different benchmark interest rates even for loans with the same benchmark interest index and first payment adjustment dates.

We exploit this variation in lookback periods, along with the volatility of 6-month Libor, in our IV strategy to assign different benchmark interest rate changes to otherwise similar borrowers. First, note that, as stated above, we focus on 6-month Libor indexed ARMs with a 6 month payment adjustment frequency as these loans comprise the vast majority of subprime ARMs originated during the 2000s boom (table 1). Moreover, to ensure that borrowers are ex-ante otherwise similar, we only consider interest rate resets around each loan's first payment adjustment episode. Thus, our assignment of different aggregate benchmark interest rates to each borrower is based on the change in 6-month Libor *between* the first interest rate measurement and first payment adjustment (the loan-level Libor change). Borrower level variation in Libor changes arises due to (1) the timing of interest rate measurement and (2) volatility in the path of 6-month Libor. Indeed, the volatile nature of Libor during the 2000s crisis (e.g., figure 2, panel 1A) creates notable variation in the change in 6-month Libor between first measurement and first adjustment across borrowers.

Our first fundamental supposition, the first stage in our 2SLS strategy, is that larger benchmark interest rate declines, as measured by Libor changes between first measurement and first adjustment, spark debt renegotiations (e.g., loan modifications).[17] Indeed, a larger reduction in 6-month Libor between first measurement and first adjustment will lead to a wider spread between the Libor rate used in the ARM rate calculation and its actual market value at first adjustment. In other words, ARM rates in such cases will be higher than had Libor been measured at first adjustment. As a large share of ARM borrowers were distressed during 2000s housing crisis, higher ARM rates likely increased the probability of default for otherwise similar borrowers. Moreover, foreclosures create deadweight losses for both borrowers and lenders

[17]Note that any deviation in the ARM interest rate at first adjustment from that computed at first measurement date was at the discretion of the servicer (lender).

(Bolton and Rosenthal, 2002). Therefore, a larger decline in Libor between measurement and payment adjustment may induce interest rate modifications, especially as PLS MBS investors were also often funded via Libor.

For the relationship between Libor changes and modifications to be causal, the difference in Libor between first measurement and first adjustment must be as good as randomly assigned (e.g., the IV independence assumption). Gupta (2019) finds that lookback periods themselves are uncorrelated with pre-treatment borrower characteristics. Yet our identification scheme adds an additional layer of exogeneity by also relying on the aggregate volatility of 6-month Libor. In all of our regression models we control linearly for the number of lookback days, akin to a time trend. So, the key identifying assumption is that the non-linear change in 6-month Libor between first interest rate measurement and first payment adjustment is independent of ex-ante borrower characteristics. To assess this assumption, we examine the correlation between various origination and pre-first interest rate measurement borrower- and zip-code level variables and the Libor change between first measurement and adjustment (e.g., balance tests). If the loan-level first measurement to first adjustment Libor difference is as good as randomly assigned, then this Libor change should be uncorrelated ex-ante borrower level characteristics. The results are in table 2, which shows coefficient estimates from separate loan-level regressions of each variable in the left column on the loan-level Libor change. Each left-hand-side variable is standardized to have zero mean and unit variance to ease interpretation across dependent variables. In each regression, we control for the lookback period (in days). Controls also include first payment adjustment fixed effects so that the estimates are a (weighted) average of correlations taken within each first payment adjustment date. Each regression is based on 350,946 loan-level observations, and robust standard errors are clustered at the three-digit zip code level.

Overall, the results in table 2 indicate that loan-level Libor changes are uncorrelated with ex-ante borrower level outcomes. All of the coefficient estimates in table 2 are small in magnitude and not statistically significant at the 1 percent level. These results extend to origination characteristics such as FICO credit score, CLTV, the initial interest rate, and the interest

rate margin (often a risk proxy for ARMs). There is also limited correlation between the Libor change and variables measured 4 months before first adjustment, including the FICO credit score, Equifax estimates of income, an indicator for if the loan was ever modified, and delinquency proxies. The final two rows of table 2 also show that loan-level Libor changes are also uncorrelated with zip code level income in 2006 and crisis-era pre-treatment house price growth measured between 2006M01 and 2007M08. Note that the coefficient on the loan-level Libor change is significant at the 5 percent level (but not at the 1 percent level) when an indicator variable for if the loan was ever 60 days delinquent as of four months before first payment adjustment. Yet this estimate is only marginally significant and all of the other ex-ante borrower level characteristics are uncorrelated with loan-level Libor changes. Indeed, the other delinquency proxies in table 2, including the number of days delinquent, if the loan was ever 90 days delinquent, or if the loan was ever 150 days delinquent, are uncorrelated with loan-level Libor changes.

With the first measurement to first adjustment 6-month Libor change in hand, we can then estimate our first stage loan-level regression that examines the impact of Libor changes on loan modifications:

$$\text{Mod}_{it} = \lambda_t + \Gamma_i X_i + \pi \mathit{LiborChange}_{it} + \eta_{it} \tag{2}$$

The dependent variable is an indicator variable that takes a value of 1 for an interest rate modification for loan i at first payment adjustment date t. We define an interest rate modification as a 1 percentage point or more difference between the ex-ante expected interest rate based on the loan contract terms using 6-month Libor at the first measurement date and the actual ARM interest rate during the first remittance period following first adjustment. Note that this modification definition aptly captures the modifications in the broader dataset as 73% of modifications identified by Moody's Blackbox satisfy this interest rate modification definition.[18]

In equation 2, λ_t represents first payment adjustment month effects, X_i is a vector of

[18] 83% of modifications identified by Moody's Blackbox are associated with an interest rate reduction of 0.5 percentage points or more. Our results are similar but smaller in magnitude as expected if we use 0.5 percentage points as the threshold for an interest rate modification. See appendix A.

borrower origination and pre-first adjustment controls with coefficient Γ_i. These controls include several origination borrower characteristics such as FICO score, CLTV, and three-digit zip code fixed effects. Controls also include borrower-level variables measured four months before first adjustment, such as the loan balance, FICO credit score, income estimates, debt-to-income proxies, and delinquency status.[19] η_{it} is the error term.

The candidate instrument is the first measurement to first adjustment 6-month Libor change for each loan, $LiborChange_{it}$. $LiborChange_{it}$ is coded so that more negative values indicate a larger Libor decline between first measurement and first adjustment. Note that the first stage effect, π, is of interest. Its inverse measures the impact of a one percentage point decline in Libor on the probability of loan modification. Hence, π captures the debt-renegotiation channel of benchmark interest rate declines and represents the transmission of aggregate benchmark interest rate reductions to subprime ARM modifications.

To identify the average causal treatment effect for compliers (loans that receive a modification based on a larger Libor decline between first measurement and first adjustment) via 2SLS using the above first stage equation, we also require the monotonicity (e.g., no defiers) assumption. Within the context of equation 2, the monotonicity assumption states that a larger Libor decline will not decrease the probability of modification. In normal economic times, this assumption may not hold as a wider spread between Libor at first measurement and prevailing market rates at first adjustment would correspond to larger relative profits for investors, making servicers less inclined to modify such loans. Yet during the 2000s housing crisis, subprime borrowers were broadly distressed. As foreclosure creates a deadweight loss for both borrow-

[19]Controls include the lookback period (in days), origination FICO credit score, Origination CLTV, the origination interest rate, the loan balance 4 months before first adjustment, and an indicator if the loan had ever been 60 days delinquent four months before first adjustment. Controls also include fixed effects for the three-digit zip code, the origination year-quarter, owner-occupied type, the purpose of the loan, the property type, the type of loan documentation at origination, the loan type, and the MBA delinquency status four months before first adjustment. We also include ventiles for the FICO credit score four months before first adjustment, the Equifax estimated debt-to-income ratio four months before first adjustment, the log of Equifax estimated income four months before first adjustment, the amount of funds available in HELOC loans relative to the size of the monthly mortgage payment four months before first adjustment, the amount funds available on credit cards relative to the size of the mortgage payment four months before first adjustment, the household income for each borrower's zip code in 2006, and the log difference in zip code level house price growth from 2006M01 to 2007M08. For these latter variables, where we convert numeric variables to ventiles, we also include a separate dummy in cases where the variable is missing so that missingness does not bias our sample.

ers and lenders (Bolton and Rosenthal, 2002), servicers thus likely had an incentive to modify these loans to avoid the fallout from default. Indeed, in robustness checks below, we separately examine various subgroups of potential defiers (e.g., ex-ante high quality borrowers) and find that the sign of the first stage coefficients for these subgroups matches the broader sample. We also remove a subset of likely defiers, borrowers who were current four months before first adjustment, and find that the results from these estimates match our main findings. Hence, defiers are unlikely to be present in our data, and the monotonicity assumption is likely to hold.

We then model the causal effect of modifications on borrower level outcomes using the following equation:

$$\mathrm{y}_{it} = \alpha_t + \gamma_i X_i + \rho \mathrm{Mod}_{it} + \varepsilon_{it} \tag{3}$$

α_t are the first adjustment month fixed effects, X_i is the vector of borrower level ex-ante characteristics (listed in footnote 19), and Mod_{it} is the modification indicator for loan i with first payment adjustment date t.

We consider several borrower level outcomes for the left-hand-side variable, y_{it}, but, as discussed below, the first variable of interest is the log monthly mortgage interest rate payment. When the dependent variable is the monthly mortgage interest rate payment, the 2SLS estimate, ρ, is the local average treatment effect (LATE) given by the ratio of (1) the average effect of the loan-level Libor change on monthly mortgage interest payments (reduced form); and (2) the average effect of the loan-level Libor change on the probability of modification (first stage; equation 2). More plainly, the 2SLS LATE estimates capture the impact of Libor change-induced modifications on monthly mortgage payments and are the causal chain that represents the transmission of benchmark interest rate declines to monthly mortgage payments via loan modification. This is the debt-renegotiation channel of monetary policy.

In addition to the independence and monotonicity assumptions discussed above, causal 2SLS estimates also require the IV exclusion restriction. The IV exclusion restriction asserts that Libor changes only affect borrower level outcomes (y_{it} in equation 3) through modifications (e.g., via the first stage in equation 2). In our case, the exclusion restriction would be violated if loan-level Libor changes affect borrower level outcomes through any channel outside of the

modification mechanism. While this assumption cannot be directly tested, we contend that the inclusion of first payment adjustment date fixed effects ensures that exclusion restriction holds. Indeed, by including first adjustment date fixed effects, we assign borrowers within the same first adjustment date with different Libor changes. Thus national changes in benchmark interest rates, such as Libor, affect borrowers' other financial assets and debts equally across treatment and control groups. This leaves modifications as the only channel through which Libor changes between first measurement and first adjustment can affect borrower level outcomes.

In alternative specifications, we also construct our main instrument using a leave-one-out, jackknife estimator, following Gupta and Hansman (2022). For each loan, the jackknife estimator captures lookback period $\times$ reset month interest rate variation by computing the mean interest rate for all other loans with the same lookback period and reset date.[20] The results using this jackknife-based instrument (appendix B) are congruent with our main findings, highlighting the robustness of our identification scheme.

5 Results

Figure 3, panel 1A plots the interquartile range for the change in 6-month Libor between first interest rate measurement and first payment adjustment (loan-level Libor changes) by first adjustment year-quarter. The sample consists of subprime ARMs (FICO $\leq$ 660 at origination). Darker colors in panel 1A correspond to a larger number of subprime ARM loans within a given first adjustment year-quarter. Overall, the plot in panel 1A highlights the sizable interquartile range (and thus treatment variation) in loan-level Libor changes across several first adjustment year-quarters. For example, the interquartile range reached over 1.5 percentage points for the loans with a first adjustment date in 2008Q1 or 2008Q4. Panel 1A also shows that most subprime borrowers experienced their first adjustment in 2007 and 2008, in line with the summary statistics highlighted in table 1.

Next, figure 3, panel 1B plots the modification and REO foreclosure rates for the baseline

[20]The jackknife estimator for loan i is the mean for interest rate for all other loans with the same lookback period ($L(i)$) and reset month ($m(i)$) at t: $z_{it} = \frac{1}{n_{L(i)\times m(i)}-1} \sum_{j=1,j\neq i}^{n_{L(i)\times m(i)}} Int_{jt}$. Int_{jt} is the interest rate for loan j at time t and $n_{L(i)\times m(i)}$ is the number of surviving loans originated lookback period $L(i)$ with reset period $m(i)$. We would like to thank Arpit Gupta for pointing us in this direction.

subprime ARMs. We define baseline subprime ARMs as those in the top quartile in terms of the first measurement to first adjustment Libor change and therefore are the loans least impacted by the instrument. In panel 1B, the probability of modification (blue dots) is defined as in equation 2, and the probability of REO foreclosure is measured within 36 months of first payment adjustment. Confidence bands correspond to ±2.5 robust standard errors clustered at the three-digit zip code level from separate regressions estimated by first adjustment year-quarter.

For the baseline subprime ARMs, panel 1B shows an interesting correlation: Loans with an earlier first adjustment year-quarter were substantially less likely to receive a modification but experienced markedly higher foreclosure rates. For example, only 2.2% of loans with a first adjustment date in 2007Q4 received modifications, but 30.9% ended up in REO foreclosure after 36 months. In contrast, 20.6% of loans with a first payment adjustment date in 2009Q3 were modified, and only 16.4% of loans in this first payment adjustment cohort ended up in REO foreclosure 3 years after first adjustment. Hence, modifications appear to be associated with lower foreclosure rates. Yet considerable changes in economic conditions over this period likely impacted both modifications and foreclosures, confounding the correlations in panel 1B. Thus, to generate causal estimates that capture the impact of Libor change-induced debt-renegotiations on borrower level outcomes, we employ the IV strategy outlined in section 4.

Panel 2A of figure 3 plots our first stage estimates. We separately estimate equation 2 by each first adjustment year-quarter to gauge the impact of Libor changes on modifications over the housing crisis and allow the coefficients on controls to vary over time. The blue dots in panel 2A represent the year-quarter coefficient estimates of π in equation 2, where confidence bands correspond to ±2.5 robust standard errors clustered at the three-digit zip code level. Note that we retain first payment adjustment month fixed effects. Thus for each year-quarter, we interpret these estimates as the average impact of a one percentage point increase in Libor on the probability of modification within each first payment adjustment month.

Overall, the blue dots in panel 2A show that Libor changes had little impact on modifications in 2007Q4 and 2008Q1, when modifications in the overall dataset were rare (panel 1B). Then

for each payment adjustment year-quarter beginning in 2008Q2, a decline in 6-month Libor causes a statistically significant increase in the probability of an interest rate modification. The coefficient estimates are much larger for loans with a later first payment adjustment date. This latter result is not surprising as the modification rate for the subprime ARMs was much lower earlier in the sample period (panel 1B). Indeed, for loans with a first payment adjustment date in 2008Q2, a 1 percentage point decline in Libor increases the probability of modification by 4.751 percentage points (robust S.E. = 0.516%; t-statistic = -9.21; first stage F-statistic = 84.83) compared to a 10.381 percentage points for 2009Q3 (S.E. = 1.871%; t-statistic = -5.55; first stage F-statistic = 30.80).

Libor declines thus incite modifications, with strong predictive power in the statistical relationship: For the entire sample, ranging for loans with a first adjustment date from 2007M10 to 2009M09, a 100 basis point decline in Libor increases the probability of modification by 5.46 percentage points (see table 3; robust S.E. = 0.30%; t-statistic = 18.23; first stage F-statistic = 332.50). As the overall modification rate for subprime ARMs is 8.6%, this estimate of 5.46 percentage points is noteworthy.

To further gauge the economic significance of our first stage estimates, the red dots in panel 2A plot the increase in the modification rate induced by loan-level Libor changes sorted by first payment adjustment year-quarter. Specifically, we multiply the first stage coefficient estimates (blue dots; panel 2A) by the Libor change moving from the fourth to the first quartile (panel 1A). We then divide this product by the modification rate for the baseline ARMs in the top Libor change quartile (panel 1B). The result is the increase in the modification rate for each year-quarter induced by the interquartile difference in loan-level Libor changes.

The red dots in panel 2A show that the Libor changes lead to economically meaningful jumps in the modification rate starting in 2008Q2. Indeed, modification rate increases ranged from 30-40% in 2008Q2-Q3, reached over 70% in 2008Q4 (just after the Lehman Crisis when the interquartile range for loan-level Libor changes was large), were over 20% in 2009Q1-Q2, and fell to under 10% by 2009Q3. The declining trend in the red dots in panel 2A (outside of the outlier in 2008Q4) perhaps corresponds to diminishing marginal increases in the modification rate with

Libor changes as the baseline modification rate rose (panel 2A). Yet the sizable increase in the modification rate during 2008Q4 indicates that benchmark interest rate declines can markedly impact debt-renegotiations in the wake of severe economic and financial market distress.

Next, the top graph in panel 2B lets the dependent variable in second stage regression in equation 3 be the log difference in the monthly mortgage interest rate payment between its actual value in the first remittance period following first payment adjustment and its ex-ante expected value. The expected values are based on loan contract terms and the value of 6-month Libor at the first interest rate measurement. The excluded instrument is the loan-level Libor change between first measurement and first adjustment. Confidence bands are based on ± 2.5 robust standard errors clustered at the three-digit zip code level. We only estimate the second stage regression for first payment adjustment year-quarters where the first stage t-statistic is greater than 2.5.

In panel 2B, the top plot documents that Libor change-induced modifications caused a large and statistically significant drop in monthly mortgage interest rate payments, ranging from about 0.20 to 0.75 log points. These decreases in monthly mortgage payments have important implications for borrower debt-service. The bottom plot in panel 2B shows point estimates from 2SLS regressions where the change in interest rate payments in dollars represents the outcome variable. These results document that Libor change-induced modifications reduced monthly mortgage payments by about \$375 per month (2009Q1) to nearly \$1200 per month (2009Q2).

Columns (1) and (2) of table 3 summarize the 2SLS estimates from Figure 3, panel 2B for our whole sample of subprime ARMs, those with a first payment adjustment between 2007M10 and 2009M09. The table also shows the corresponding first stage, reduced form, and OLS estimation output. The 2SLS estimates (panel A) document that Libor change-induced modifications lower interest rate payments at first adjustment, relative to those predicted at first measurement, by a statistically significant 0.296 log points (column (1)) or \$480 per borrower per month (column (2)). These estimates are economically meaningful. Indeed, the 2SLS estimate from column (2) implies that Libor change-induced modifications reduce mortgage payments by on average over \$5500 per year.

The reduced-form estimates in panel B document the total impact of Libor declines on interest rate payments for all loans in our sample (regardless of whether they received a modification). These estimates indicate that a 100 basis point decline in 6-month Libor lowers monthly payments by 0.016 log points or $26, corresponding to a total annual decline interest rate payments for all borrowers in the sample of over $100 million.

Columns (1) and (2) of table 3, panel C indicate that the OLS estimates of the impact of interest rate modifications are biased downward. Indeed, the OLS coefficient in column (2) is over $180 lower than the 2SLS estimate, perhaps suggesting that servicers select loans for modification that result in lower interest rate payment reductions even after controlling for the loan balance four months before first payment adjustment.[21]

In table 3, column (3), the outcome variable is the difference in the back-end debt-to-income (DTI) ratio from four months before first adjustment to one month after first adjustment. Back-end DTI is estimated from the consumer credit panel by Equifax. As Equifax reports back-end DTI as a unitless score, we normalize the dependent variable by the standard deviation of DTI four months before first adjustment. Thus, the reported coefficient in column (3) represents the change in standard deviations in the back-end DTI ratio from four months before first adjustment. Panel A documents that Libor change-induced modifications reduce back-end DTI by an economically meaningful and statistically significant 0.21 standard deviations. This finding thus indicates that Libor change-induced modifications result in a broad easing of debt service burdens for distressed borrowers.

Next, table 3, column (4) assesses the durability of Libor change-induced interest rate modifications. In particular, we let the dependent variable be the difference in the ARM interest rate between the first payment adjustment and six months after the first payment adjustment (corresponding to the second payment adjustment).[22] We aim to determine if the interest

[21]The list of controls used in table 3 is in footnote 19.

[22]For loans that become inactive (e.g., due to a foreclosure, the loan being liquidated with a loss to the investor, or being paid in full), we use the last available interest rate between the first and second payment adjustments. Thus, there may be survivorship bias in this regression. We also only look at interest six months after first adjustment as the share of inactive loans rises over time. This growing share of inactive loans may increasingly bias interest rate comparisons of borrowers who received modifications relative to those who do not.

rates between modified and non-modified loans converge following first adjustment, perhaps as servicers modify loans previously not modified between first measurement and first adjustment. The 2SLS estimate in panel A, column (4) instead indicates that modifications between first measurement and first adjustment are associated with a further 0.63 percentage point drop in the mortgage interest rate 6 months after first adjustment. Thus, the borrower benefits of Libor change-induced debt-renegotiations between first measurement and first adjustment, relative to the overall sample, appear to persist immediately following modification.

Finally, the dependent variable in table 3, column (5) is an indicator that equals 1 if the borrower loses their home while in distress: If the loan entered into REO foreclosure or if the loan was liquidated with a loss relative to the market sale value of the underlying collateral (henceforth, foreclosures). Note that controls include MBA delinquency status fixed effects four months before first adjustment. The 2SLS estimate can thus be interpreted as the weighted average of the effect of Libor change-induced modifications within each MBA delinquency status bin, holding other controls constant.[23]

The 2SLS results in table 3, column (5) indicate that modifications have an immediate impact on foreclosures: A Libor change-induced modification reduces the probability of foreclosure by nearly 20 percentage points six months after first adjustment. Hence, Libor change-induced debt-renegotiations provide borrowers receiving a modification an immediate reprieve from foreclosure. Below in section 5.5, we further assess the dynamic impacts of modifications on foreclosures and other borrower-level outcomes.

5.1 Identification Strategy Robustness

To further assess the robustness of our IV identification strategy and research design, figure 3, panel 3 plots falsification tests from separate regressions where the left-hand-side variable is a credit performance indicator (panel 3A) or a mortgage performance variable (panel 3B) measured 1 year before first payment adjustment. In these regressions, the key right-hand-side variable is the Libor change between first measurement and first payment adjustment, analogous

[23]See footnote 19 for the full set of origination and pre-first payment adjustment control variables. Our sample includes all loans (except those that entered REO or were liquidated with a loss in the month before first adjustment) regardless of delinquency status.

to our first stage regressions in equation 2 and panel 2A. Controls only include origination loan characteristics, and all dependent variables are standardized to have zero mean and unit variance. The plotted bands in panel 3 correspond to ±2.5 robust standard errors clustered at the three-digit zip code level. Generally, the results in panel 3 combine to imply that first measurement to first adjustment Libor changes are uncorrelated with these credit and mortgage performance variables, congruent with the assumption that the Libor instrument is independent of ex-ante borrower characteristics.

Also, recall that our 2SLS estimates depend on monotonicity. This assumption asserts that a decline in 6-month Libor between first measurement and first payment adjustment will not decrease the probability of modification. For defiers, a reduction in Libor *decreases* the probability of an interest rate modification, a violation of monotonicity. Indeed, potential defiers may arise under normal economic circumstances as a decline in Libor between first measurement and first adjustment would yield larger profits for PLS investors and may reduce modification incentives. However, in the wake of the housing crisis, fears of widespread mortgage default abounded as foreclosures create deadweight losses for borrowers and lenders (Bolton and Rosenthal, 2002). Thus, during this time, the benefits of lender modification likely outweighed any forgone interest payments from an elevated Libor ARM measurement–market rate spread.

More specifically, we consider three specific subgroups of likely defiers: Loans current four months before first payment adjustment (appendix table D1); non-sand state loans (appendix table F1); and loans associated with non-subprime (FICO score > 660) borrowers current four months before first payment adjustment whose homes were in zip codes that experienced positive house price growth from 2006M01 - 2007M08 (appendix table G1). In all these cases, the first stage coefficient on the Libor change between first measurement and first adjustment instrument has the expected negative sign, congruent with the monotonicity, no-defiers assumption. Hence, Libor declines appear only to increase modification probabilities. Furthermore, in appendix C, we also remove current loans (e.g., potential defiers) and find that these estimates are in line with our main findings. Altogether, these results suggest that the monotonicity, no-defiers assumption holds in our data.

5.2 First Stage Estimates by Occupancy Status

Figure 4 displays output from our first stage regression by occupancy status, where our objective is to compute separate estimates for owner-occupied borrowers, non-owner-occupied borrowers, and borrowers whose mortgage was secured by a second home. Non-owner-occupied borrowers are typically classified as real estate investors and purchase homes to accrue rents and speculate on house price appreciation. These borrowers are thus seen as more sophisticated, having more real estate market experience, and less susceptible to biases that lead to sub-optimal financial decisions. Likewise, borrowers whose loans were backed by second homes also likely have more real estate market experience compared to owner-occupied borrowers. This experience should mitigate behavioral biases (List, 2003) in their mortgage and related financial decisions. Real estate investors and borrowers with second homes thus may have been more aware of the renegotiation opportunities, more likely to pursue modification, and more adept at navigating the modification process. Larger increases in modification probabilities for these borrowers, in response to changes in benchmark rates relative to the baseline owner-occupied borrowers, all else equal, would indicate that investment experience and financial acumen are important determinants for modification and renegotiation outcomes.

Panel A in figure 4 plots estimates from our first stage equation (equation 2), estimated separately by occupancy status. For baseline, owner-occupied borrowers who make up 87 percent of our sample, a one percentage point decline in Libor increased the probability of modification by 5.62 percentage points (robust S.E. = 0.26%), consistent with our main estimates. In comparison, real estate investors (non-owner-occupied borrowers) and borrowers with more experience (borrowers whose loans were backed by second homes) benefited from substantially higher modification probabilities. Due to a one percentage point decline in Libor, the probability of modification rose 8.91 percentage points (robust S.E. = 0.86%) for real estate investors and 10.84 percentage points (robust S.E. = 2.05%) for more experienced borrowers. Thus, modification probabilities were over 50 percent higher for investors and experienced borrowers, where these differences relative to owner-occupied borrowers are statistically significant (panel B). In total, the results from figure 4 imply that borrower financial acumen and experience are

key drivers in debt-renegotiation process.

5.3 First Stage Estimates by Origination FICO Bins and Delinquency Status

In figure 5, panel A, we re-estimate our first stage relationship from equation 2 separately by origination FICO score bins and current (e.g., 30 or less days delinquent) versus non-current (60 or more days delinquent) delinquency status. The non-end point origination FICO score bins span 40 FICO points (0.65 standard deviations). We also use 60 or more days delinquent as the cutoff for non-current borrowers as 60 days delinquent is typically used as the threshold for default in the mortgage literature. For robustness, appendix figure I1 instead uses a 90 day delinquency cutoff and finds similar results. Figure 5, panel A shows the coefficient estimates on the Libor change between first measurement and first adjustment ($\hat{\pi}$) estimated separately by FICO bin and delinquency status. The size of the dots in the figure corresponds to the number of observations in each bin. All bins appear to be well-populated except for the 720-840 FICO, 60 or more days delinquent bin that consists of just 4600 observations. Hence, few high FICO score borrowers become delinquent before first adjustment.

Our aim with this analysis is to compare borrowers along two key dimensions: Distress and ex-ante quality. We proxy distress by comparing current and delinquent borrowers four months before first payment adjustment to determine if Libor changes have heterogeneous impacts along the non-distressed–distressed borrower spectrum. We then examine the effects of Libor changes on modification probabilities by ex-ante borrower quality via assessments of how variation in origination FICO scores, a key default predictor known by services, affects the Libor change–modification relationship.

First, panel A shows within credit score bins that the impact of a Libor change on the probability of modification is similar for current and non-current borrowers. Hence, benchmark interest rate declines do not prompt debt-renegotiation differences along the current–delinquent borrower dimension.[24] Indeed, the results in panel A instead indicate that the impact of Libor changes on the probability of modification is approximately equally efficacious for current and delinquent borrowers within all plotted credit score bins. For the full sample with both non-

[24]The largest cluster robust p-value associated with a difference between current and non-current borrowers by origination FICO bin is 0.202.

subprime and subprime borrowers (e.g., all credit scores), the difference in the probability of modification between current and delinquent borrowers for a one percent change in Libor is nearly a precisely estimated zero (estimate = -0.004; robust S.E = 0.005; p-value = 0.42). For a subsample consisting of just subprime borrowers (FICO $\leq$ 660), the difference in the Libor change–modification relationship between current and delinquent borrowers is also small (estimate = 0.004; robust S.E = 0.006; p-value = 0.48).

Next, figure 5, panel B plots the difference in the first stage estimates relative to the (560, 600] FICO bin by delinquency status. The midpoint of the (560, 600] FICO bin is just below the 25th origination FICO percentile of 589. Also, note that the origination FICO subprime threshold is 660 and that the standard deviation of FICO is 61. Thus, the upper limit of the (560, 600] baseline bin is about 60 FICO points, or 1 standard deviation, below the subprime threshold.

For delinquent borrowers (red dots), those in default facing the possibility of foreclosure, there is little change in the relationship between Libor and the probability of modification moving across credit score bins. Indeed, note that the 75th percentile of origination FICO in our sample is 667, about the midpoint of the (640,680] FICO bin. The difference in estimates, those that measure the impact of Libor changes on the probability of modification, moving approximately along the origination FICO interquartile range (from the (560, 600] bin to the [640,680] bin) is nearly zero (estimate = -0.001; S.E. = 0.015; p-value = 0.94). All of the other bins where origination FICO is below 720 also have estimates similar to the (560, 600] bin.[25] Thus, origination credit score appears to have a limited impact on the probability of modification, given that the borrower is facing delinquency.

Finally, for current borrowers (blue dots in figure 5, panel B), higher credit scores translate into increases in Libor change-induced modification probabilities. Services, who typically are more willing to modify ex-ante higher quality loans, may be driving this result. Likewise, high FICO borrowers are often more financially literate and may be more likely to pursue

[25]For delinquent borrowers, the coefficient on Libor change is 4 percentage points smaller for loans with an origination FICO in the upper, (720, 840] bin relative to the (560, 600] bin. The difference is not statistically as there are only 4600 delinquent loans in the (720, 840] FICO bin.

modification, in line with our results from section 5.2.

5.4 First Stage Estimates Across Geographic Sub-markets

Next, figure 6 examines the impact of Libor changes on modifications, akin to figure 3, panel 1B using equation 2, across geographic sub-markets. We sort housing markets first by 2006M01-2007M08 zip code house price growth terciles (panel A) and then sand states (AZ, CA, FL, NV) versus the full sample (panel B). Our aim with these additional tests is to determine if the impact of Libor changes on modifications varies across geographic sub-markets sorted by 2000s crisis-era house price growth.

In panel A, the plotted coefficient estimates are from separate regressions based on equation 2 by zip code house price growth tercile and first payment adjustment date. The red dots represent the top house price tercile (highest house price growth from 2006M01-2007M08), the green dots signify the middle house price tercile, and the blue dots correspond to the bottom house price tercile (lowest house price growth). Thus, the inverse of the plotted coefficient estimates represents the impact of a 1 percentage point decline in Libor on the probability of modification ($\hat{\pi}$ based on equation 2). We also examine if the effects of Libor changes on the probability of modification statistically differ across groups. To do so, in panel A we let a circle indicate the coefficient estimate for the top house price growth tercile, a square correspond to no statistical difference compared to the top house price growth tercile, and a triangle represents statistical difference (p-value < 0.01) relative to the top house price growth tercile. As in figure 3, confidence bands correspond to ± 2.5 robust standard errors clustered at the three-digit zip code level.

Overall, the plotted coefficients in panel A indicate that the effects of Libor changes on modification probabilities vary little across geographic sub-markets grouped by zip code house price growth terciles. Indeed, only in 2007Q4 do Libor changes induce a lower probability of modification for the loans in the bottom zip code house price growth tercile. For the full sample of subprime ARMs (FICO ≤ 660) with a first payment adjustment date between 2007M10 and 2009M09, the Libor change–modification relationship is also similar across house price growth terciles: A 100 basis point decline in Libor increases the probability of modification by 5.56

percentage points (robust S.E. = 0.31%) for loans collateralized by homes in zip codes whose house price growth is in the top tercile. In comparison, that same Libor decline leads to a 5.19 percentage point gain (robust S.E. = 0.31%) in the probability of modification for homes collateralized by homes in zip codes whose house price growth is in the bottom tercile. The difference in these estimates, 0.37 percentage points, is small and not statistically significant.

Next, panel B of figure 6 repeats panel A but runs the regressions separately for the full sample (red dots) and the sand states (blue dots). In panel B, the circles correspond to the coefficient estimates for π in equation 2 for loans in the lowest zip code house price growth tercile in either the sand states or full sample, respectively. Triangles correspond to coefficient estimates for loans in the top house price tercile for the full or sand states samples. We only plot these coefficients if they are statistically different from the bottom house price terciles (circles). Congruent with panel A, there is little variation across geographic sub-markets more adversely impacted by negative house price growth shocks. These results thus likewise indicate that the effects of Libor changes on modifications vary little across geographic sub-markets.

5.5 The Dynamic Impacts of Libor Change-Induced Modifications on Borrower Outcomes

Next, we examine the dynamic impacts of Libor change-induced modifications on various borrower level outcomes using the 2SLS approach outlined in section 4. We modify equation 3 to examine borrower-level outcomes j periods after first adjustment:

$$\mathrm{y}_{i,t+j} = \alpha_t + \gamma_i X_i + \rho \mathrm{Mod}_{it} + \varepsilon_{it} \tag{4}$$

where $y_{i,t+j}$ is a given outcome associated with loan i, j months after first payment adjustment. We estimate equation 4 separately for each j. The excluded instrument is the first measurement to first adjustment Libor change for loan i. Thus, the 2SLS effect, ρ, can be interpreted as the causal impact of a Libor change-induced modification on $y_{i,t+j}$.

In figure 7, we first examine the effects of Libor change-induced modifications on an indicator for real estate owned (REO) foreclosures or loans liquidated with a loss relative to the market sale value of the underlying collateral[26] (henceforth, foreclosures; panel A) as well as an indicator

[26]For example, a forced sale.

for pre-payments (without any loss for the investor; panel B). The horizontal axis is the number of months after first adjustment, and the confidence bands correspond to ±2.5 robust standard errors clustered at the three-digit zip code level. The sample includes all subprime loans (FICO ≤ 660) with first adjustment between 2007M10 and 2009M09. We let foreclosure or pre-payment be absorbing states: Once a loan enters foreclosure or is pre-paid during month $t + j$ after first adjustment, it remains in that state for all subsequent months.

The red lines in figure 7 correspond to a base model that only includes first payment adjustment month fixed effects (where the excluded dummy corresponds to October 2007) and controls for the following demeaned variables: The lookback period (in days), the FICO credit score at origination, CLTV at origination, the initial interest rate, and the loan balance 4 months before first payment adjustment. Thus, the intercept in the left plot in panel A tracks the probability of foreclosure for a loan that did not receive a Libor change-induced modification with a first payment adjustment date in October 2007 and mean values for the aforementioned credit risk predictors (e.g., baseline loans). In panel A, the path of the intercept indicates that the probability of foreclosure for these baseline loans increased substantially over the sample period. Indeed, after 48 months (4 years), over 45% of such borrowers entered foreclosure.

The right plot in panel A shows the 2SLS estimates. Libor change-induced modifications markedly lower the foreclosure probabilities after first adjustment. The effects are immediate. After just 12 months, a Libor change-induced modification reduces the probability of foreclosure by 20 percentage points (red line; robust S.E. = 5.91%; t-statistic = 3.51). From there, the beneficial effects of Libor change-induced modifications escalate: After 48 months, the probability of foreclosure for loans that receive a Libor change-induced modification falls approximately 37 percentage points (red line; robust S.E. = 7.10%; t-statistic = 5.20). Hence, Libor change-induced modifications have a statistically significant and economically meaningful effect on the foreclosure rate in the baseline model.

The green line in figure 7 uses a full set of controls.[27] The 2SLS estimates in panel A are similar with the inclusion of these controls. Yet the standard errors fall slightly, supporting

[27] Controls are listed in 19.

the IV independence assumption as these variables have predictive power for foreclosures but are generally uncorrelated with the instrumented modification indicator. Table 4, column (1) reports the 2SLS, first stage, reduced form, and OLS estimates when the dependent variable is an indicator for foreclosure after 48 months (e.g., if the loan ever entered REO foreclosure or was liquidated with a loss). The 2SLS estimate in table 4, panel A equals the last point estimate of the green line (with controls) in the right plot in figure 7, panel A. This estimate shows that Libor change-induced modifications lower the probability of foreclosure by a statistically significant 41 percentage points (t-statistic = 6.69).

The reduced form estimates in column (1) of table 4, panel B document that a 100 basis point Libor decline reduces the probability of foreclosure for our entire sample of subprime ARMs by 2.3 percentage points (t-statistic = 7.67), regardless of whether the loan received a modification. Thus, Libor declines have a statistically significant and economically meaningful impact on foreclosures for our entire sample of subprime ARMs.

Next, column (1) of table 4, panel C suggests that the OLS estimates based on equation 4 are biased towards zero. Indeed, the OLS estimates indicate that an interest rate modification, whether a Libor change induces it or not, lowers the probability of foreclosure by just 2.8 percentage points. This small point estimate may be related to services selecting modifications that result in smaller monthly payments (table 3, column (2), panel C) or the convergence of ARM interest rates in OLS estimates following first adjustment (table 3, column (4), panel C).

Figure 7, panel B plots the dynamic impacts of Libor change-induced modifications on pre-payments (without any loss to the investor). The left panel shows that the probability of pre-payment for baseline loans leveled off after about 20 months following first payment adjustment and only reached about 18% after 48 months. The 2SLS estimates in the right panel show that after 48 months, the probability of pre-payment for loans with Libor change-induced modifications increased by about 6 percentage points, but this estimate is not statistically significant (see also table 4, column (2)).

Figure 8 expands our proxy for borrower distress and examines the effects of Libor change-induced modifications. Specifically, we let the outcome variable be an indicator variable equal to

1 if the borrower ever lost their home to foreclosure (REO foreclosure or liquidated with a loss) or, for active loans, if the loan is seriously delinquent j months after first adjustment. Panel A panel tracks estimated effects for loans in foreclosure or that were 90 or more days delinquent, while panel B uses a 180 day delinquency threshold. First, the left plot of panel A tracks baseline subprime ARM loans with mean origination and pre-first adjustment mortgage characteristics and a first payment adjustment in October 2007 that did not receive a Libor change-induced modification. The left plot documents that 60% of the baseline subprime ARM borrowers entered foreclosure or were 90 or more days delinquent 25 months after first adjustment. This sizable point estimate highlights the broad distress faced by these borrowers in the aftermath of the 2000s housing crisis. Yet the right plot in figure 8 shows that Libor change-induced modifications have nearly no combined impact on foreclosures and serious delinquencies. Indeed, after 48 months, column (3) of table 4, panel A shows that the effect of Libor change-induced modifications on the subsequent probability of foreclosure or serious delinquency is nearly a precisely estimated zero. For example, the reduced-form estimate in panel B is just 0.09% (robust S.E. = 0.35%; t-statistic = 0.25). When we use 180 days as the delinquency threshold in figure 8, panel B and table 4, column (4), the 2SLS estimates remain statistically insignificant, though they are slightly larger in magnitude. Hence, Libor change-induced modifications do not appear to have longer-run curative outcomes for subprime borrowers. Instead, the beneficial impacts of these modifications are offset by higher late-stage delinquencies, nullifying any positive foreclosure effects associated with the Libor change-induced modifications.

Columns (3) and (4) of table 4, panel C report the OLS estimates when the outcome variable is an indicator for if the loan ever entered into foreclosure or is 90 days delinquent 48 months after first adjustment (column (3)) or in foreclosure or 180 days delinquent (column (4)). Interestingly, these OLS estimates indicate that modifications are correlated with reduced borrower distress over the longer run. After 48 months, modification is correlated with a reduction in the probability of foreclosure or serious delinquency of 2.8 percentage points (column (3)) to 3.3 percentage points (column (4)), with t-statistics for both of these estimates over 9.5. Thus, these results suggest that servicers are more likely to select borrowers for modification who are

less likely to enter foreclosure or linger in serious delinquency over the longer term.

Figure 9 restricts the sample to borrowers that never lose their home to foreclosure. In panel A, the dependent variable is an indicator equal to 1 if the borrower ever paid off their mortgage (without loss) or is current j months after first adjustment. The coefficient estimates in panel A represent the probability that a borrower is current or has ever paid off her mortgage, relative to the sample of borrowers who never entered foreclosure. Results indicate that receiving a Libor change-induced modification is associated with a 25 percentage point reduction in the probability of being current or having paid off the mortgage 24 months after first adjustment. After 48 months, the probability that treated borrowers have ever paid off their mortgages or are current falls by 29.8 percentage points (table 4, panel A, column (3)). In marked contrast, the OLS estimates in panel C, column (5) of table 4 imply that borrowers who receive a modification, but do not lose their homes to foreclosure, are 1.6 percentage points (robust S.E. = 0.47%) more likely to have paid off their mortgage or be current 48 months after first adjustment. Hence, servicers appear to choose to modify mortgages that are likely to be current over the longer term.

Finally, in panels B and C of figure 9 and columns (6) and (7) of table 4, the dependent variable is the probability that the borrower lingers in late stage delinquency, given that they never lost their home to foreclosure. These results confirm that borrowers who received a Libor change-induced modification were more likely to linger in late-stage delinquency. In contrast, the OLS estimates in table 8, panel C suggest that there is servicer selection into modifying mortgages with a lower probability of lingering in late-stage delinquency.

In appendix H, we re-estimate our 2SLS regressions for only real estate investors proxied by non-owner-occupied borrowers. Benchmark interest rate declines led to smaller foreclosure reductions for these borrowers. Yet, like in our full sample, such interest rate reductions did not induce longer run curative outcomes. Results estimated separately for owner-occupied borrowers are similar to those for our full sample, as owner-occupied loans make up 87 percent of our sample.

6 Conclusion

This paper uses a 2SLS research design to examine the short- and long-run borrower-level effects of Libor change-induced debt-renegotiation during a crisis period. We find that Libor declines substantially increase debt-renegotiation. Further, those Libor change-induced modifications reduce borrower debt-service costs by an average of approximately $480 per month. In line with lower debt-service payments limiting defaults, results show that Libor change-induced modifications markedly lower subsequent foreclosure probabilities. However, the surviving borrowers are negatively selected, as they are less likely to be current in loan payment and more likely to linger in serious delinquency. These longer-run adverse outcomes for surviving treated borrowers offset the lower foreclosure probabilities associated with modification.

Our results highlight the limits of interest rate reductions in aiding distressed borrowers during a crisis period. Falling interest rates may spark debt-renegotiation and lower debt service payments; however, more sophisticated borrowers are more likely to take advantage of renegotiation opportunities. Moreover, the overall economic benefits of interest rate declines may ultimately be reduced due to recurrent borrower non-performance. Future research should aim to test the external validity of our estimates to other markets and time periods as the performance of distressed debt is of first-order importance for policymakers implementing crisis response. For example, following the COVID-19 shock, the Federal Government and Federal Reserve implemented new liquidity facilities and related monetary stimulus in order to reduce interest rates and provide relief for distressed borrowers. Congruent with our results, evidence suggests that more sophisticated borrowers, who likely had greater awareness of and resources to partake in these programs, received government-backed bank loans first.[28] Moreover, in the wake of the COVID-19 policy interventions, bankruptcies in aggregate changed little, in line with our findings indicating that lower interest rates reduce default and foreclosure.[29] Yet the longer term performance of distressed borrowers following the COVID-19 crisis is not yet known, yielding an important opportunity for future research.

[28] "Banks Gave Richest Clients 'Concierge Treatment' for Pandemic Aid." *New York Times*. April 22, 2020.
[29] "Zombies Are on the March in Post-Covid Markets." *Bloomberg News*. June 14, 2021.

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Table 1: Counts and Summary Statistics for Subprime and Prime ARM Loans by Interest Rate Index

							First Payment Adj. Date by Monetary Policy Episode Within Each Row (%)			
Interest Rate Index	Interest Rate Type	Payment Adj. Freq. (Months)	Num. of Loans	% of Loans By Panel	Mean Orig FICO	Mean Orig LTV	Pre-Fed Funds Easing	Fed Funds Easing	QE1	Post-QE1
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Panel A: Top 5 Subprime ARM Categories (FICO $\leq$ 660)										
Libor	Libor 6-month	6	1,781,474	74.21	599.13	81.85	29.33	45.77	19.43	5.47
Libor	Libor Unknown	6	242,982	10.12	594.98	81.54	13.68	51.10	28.85	6.37
Unknown	Unknown	6	78,248	3.26	603.30	82.43	17.16	33.49	39.67	9.68
Libor	Libor 12-month	12	49,233	2.05	635.98	76.27	5.72	6.72	11.59	75.96
Treasury	Treasury 1 year	1	48,402	2.02	635.07	76.30	64.73	27.55	0.41	7.32
Panel B: Top 5 Non-Subprime ARM Categories (Fico > 660)										
Libor	Libor 6-month	6	916,418	33.20	710.73	79.34	18.02	30.08	16.47	35.43
Libor	Libor 12-month	12	477,127	17.29	734.82	73.48	3.24	7.90	12.82	76.04
Treasury	Treasury 1 year	1	243,126	8.81	720.66	75.88	67.52	25.13	0.22	7.13
Treasury	Treasury 1 year	12	177,301	6.42	741.08	71.57	4.59	11.42	17.26	66.73
Other	Other	1	175,917	6.37	720.46	59.94	82.49	16.18	0.17	1.16

Notes: Adjustable Rate Mortgage (ARM) Counts and Summary Statistics by ARM Index Category by subprime (FICO $\leq$ 660) and prime (FICO > 660) categories. Only loans outstanding in September 2009, at the start of the Fed's QE Easing Cycle, are included. Column (1) shows the broad interest rate index category, while column (2) prints a more specific interest rate type. Column (3) shows how often the interest rate and interest rate payments adjust for the ARM loans. Column (4) counts the number of loans by each row, while column (5) shows the percent of loans for a given ARM interest rate index type within each panel. Columns (6) and (7) tabulate mean origination FICO credits scores and loan-to-value (LTV) ratios. Finally, columns (8) - (11), within each row, show the percent of loans whose first payment adjustment date falls within a given monetary episode (Pre-Conventional Monetary Easing Episode (pre-2007M09; column 8), Conventional Monetary Easing Episode (2007M09-2008M11; column 9), QE1 (2008M11-2010M02; column 10), post-QE1 (post-2010M02; column 11).

Table 2: Coefficient Estimates from Regressions of Pre-Treatment Borrower Outcomes on the Change in 6m Libor between First Measurement and First Payment Adjustment

LHS Var	Estimate (1)	Std. Error (2)	t-statistic (3)	p-value (4)
Origination FICO Credit Score	0.010	0.009	1.216	0.224
Origination CLTV	−0.005	0.010	−0.507	0.612
Initial Interest Rate	0.007	0.008	0.968	0.333
ARM Interest Rate Margin	0.012	0.008	1.555	0.120
FICO Credit Score 4 Mths Before First Adj.	0.012	0.008	1.524	0.127
Equifax Income Estimate 4 Mths Before First Adj.	−0.015	0.009	−1.640	0.101
Loan Balance 4 Mths Before First Adj.	−0.017	0.009	−1.896	0.058
Ever Modified 4 Mths Before First Adj.	−0.018	0.012	−1.499	0.134
Days Delinquent 4 Mths Before First Adj.	0.010	0.009	1.133	0.257
Ever 60 Days Delin 4 Mths Before First Adj.	−0.020	0.009	−2.200	0.028
Ever 90 Days Delin 4 Mths Before First Adj.	−0.005	0.009	−0.564	0.573
Ever 150 Days Delin 4 Mths Before First Adj.	−0.004	0.009	−0.433	0.665
Zip Code Household Income in 2006	0.012	0.008	1.443	0.149
Zip Code House Price Growth, 2006M01-2007M08	0.007	0.010	0.719	0.472

Notes: Left-hand-side variables are standardized to have zero mean and unit variance. The reported coefficient estimates correspond to a regression of the left-hand-side variable on the change in 6-month Libor between first measurement and first payment adjustment, where each regression is estimated separately by row. Controls include the number of days between first measurement and first payment adjustment as well as first payment adjustment month fixed effects. Regressions are based on 350,946 loan-level observations. Robust standard errors are clustered at the three-digit zip code level.

Table 3: Regression Estimates at First Payment Adjustment

	Dependent variable:				
	At First Adj.			6-months After First Adj.	
	ln(Rate Paymt), First Adj. − Meas.	Rate Paymt $, First Adj. − Meas.	ΔDTI, Back-End (SDs)	Int Rate, 6m Post Adj. − First Adj.	Ever REO or Liq with Loss
	(1)	(2)	(3)	(4)	(5)
Panel A: 2SLS Estimates					
Modification Indicator	−0.2962	−480.8589	−0.2109	−0.6286	−0.1948
	(0.0110)	(23.8340)	(0.0912)	(0.2226)	(0.0396)
First Stage Coef on Libor Diff IV	−0.055	−0.055	−0.059	−0.055	−0.055
First Stage F-stat	332.50	332.50	368.26	332.50	332.50
Panel B: Reduced Form					
Libor Diff Between First Meas & Adj.	0.0162	26.3498	0.0124	0.0344	0.0107
	(0.0008)	(1.6156)	(0.0054)	(0.0114)	(0.0021)
Panel C: OLS Estimates					
Modification Indicator	−0.2156	−293.6072	−0.0436	0.9427	−0.0457
	(0.0015)	(8.1677)	(0.0049)	(0.0095)	(0.0027)
Observations	350,440	350,440	326,434	350,440	350,440
Controls	✓	✓	✓	✓	✓

Notes: Regression estimates around first payment adjustment. Controls are listed in footnote 19.

Table 4: Regression Estimates 48 Months After First Adjustment

	Dependent variable:						
	All Loans				Never REO or Loss After 48 Months		
	Ever REO or Loss	Ever Paid Off	Ever REO or Loss, or Is Delin90+	Ever REO or Loss, or Is Delin180+	Is Delin $\leq$ 30 or Ever Paid Off	Is Delin90+	Is Delin180+
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: 2SLS Estimates							
Modification Indicator	−0.4151	0.0608	−0.0161	−0.1099	−0.2981	0.3195	0.1996
	(0.0625)	(0.0358)	(0.0633)	(0.0662)	(0.0921)	(0.0893)	(0.0907)
First Stage Coef on Libor Diff IV	−0.055	−0.055	−0.055	−0.055	−0.053	−0.053	−0.053
First Stage F-stat	332.50	332.50	333.52	333.52	203.24	203.24	203.24
Panel B: Reduced Form							
Libor Diff Between First Meas & Adj.	0.0227	−0.0033	0.0009	0.0060	0.0159	−0.0171	−0.0107
	(0.0034)	(0.0020)	(0.0035)	(0.0037)	(0.0047)	(0.0045)	(0.0047)
Panel C: OLS Estimates							
Modification Indicator	−0.0279	−0.0076	−0.0279	−0.0325	0.0324	−0.0357	−0.0409
	(0.0029)	(0.0014)	(0.0029)	(0.0030)	(0.0040)	(0.0038)	(0.0038)
Observations	350,440	350,440	350,050	350,050	210,526	210,526	210,526
Controls	✓	✓	✓	✓	✓	✓	✓

Notes: Regression estimates 48 months after first payment adjustment. Controls are listed in footnote 19.

Figure 1: The Libor Change First Stage and Reduced Form

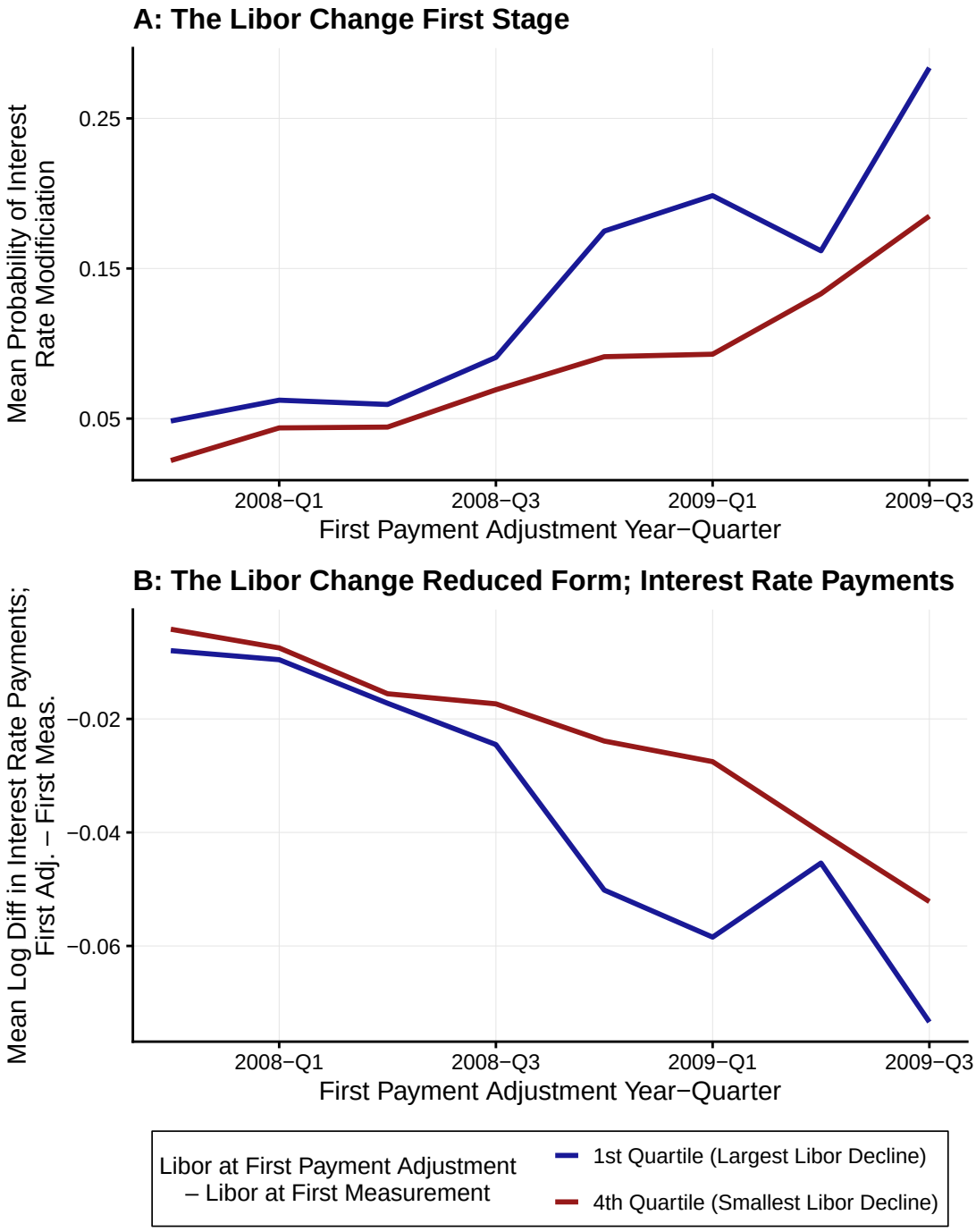


Figure 2: Monetary Policy, Libor Shocks, Subprime ARM Rates, and Modifications

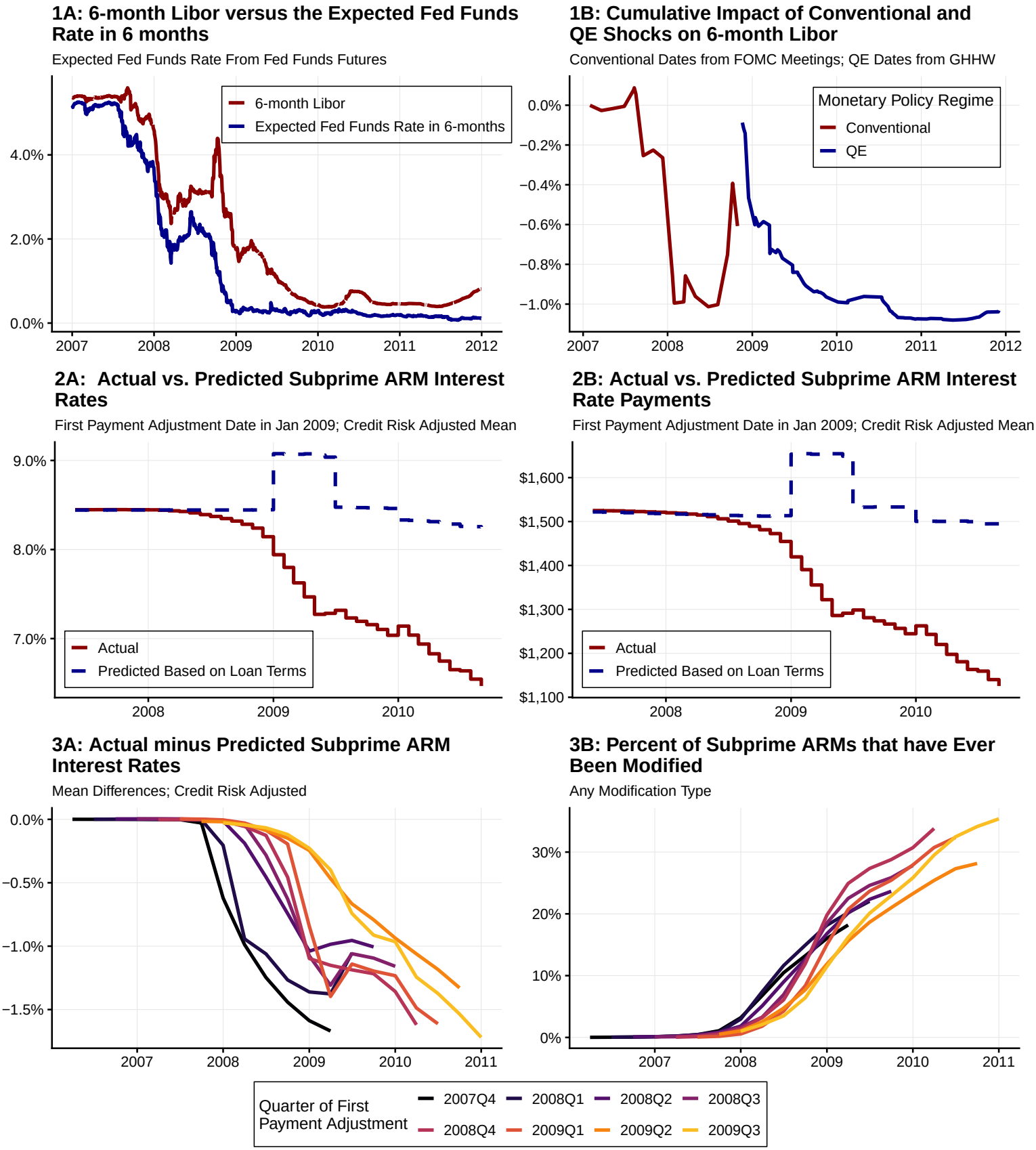
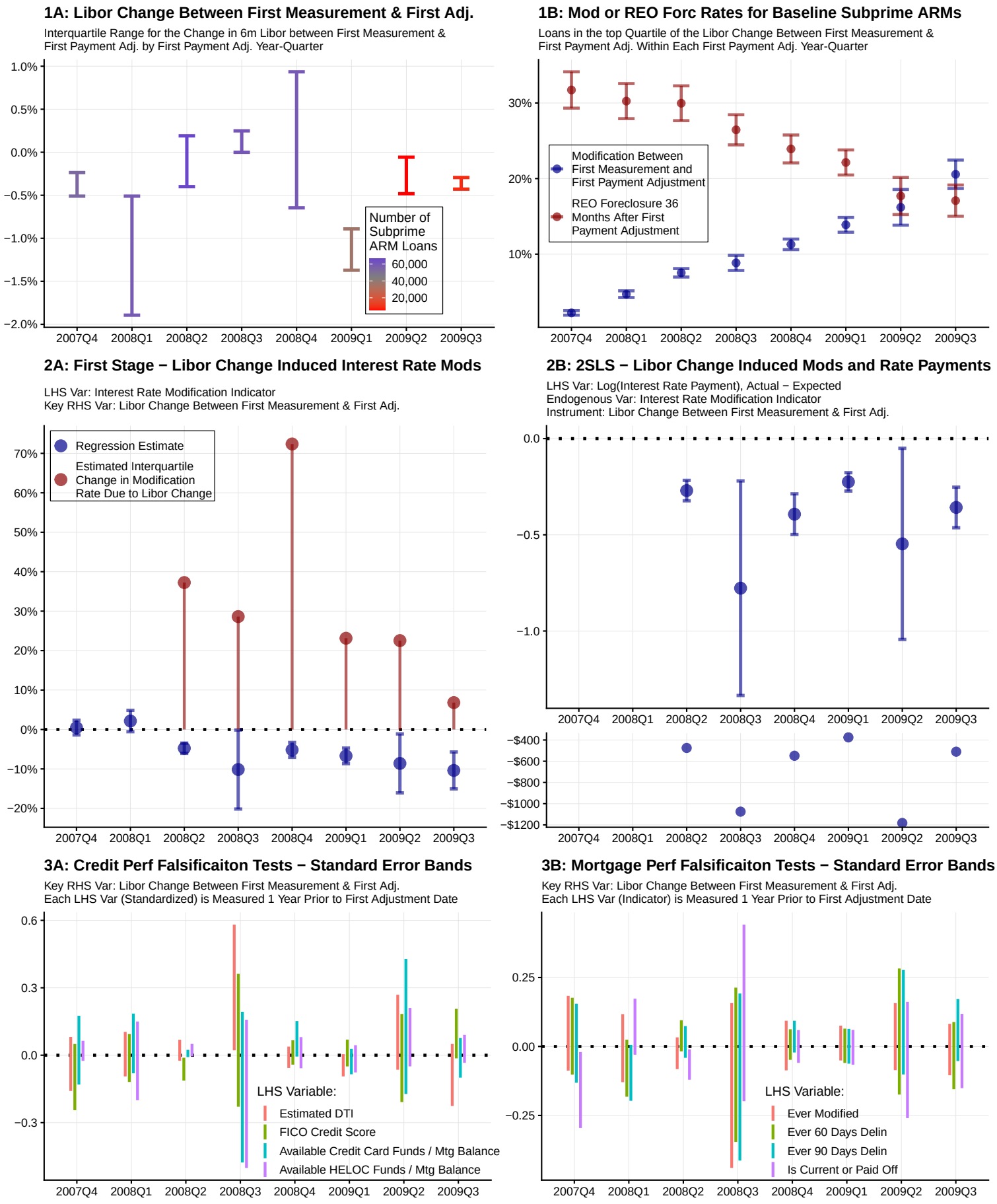
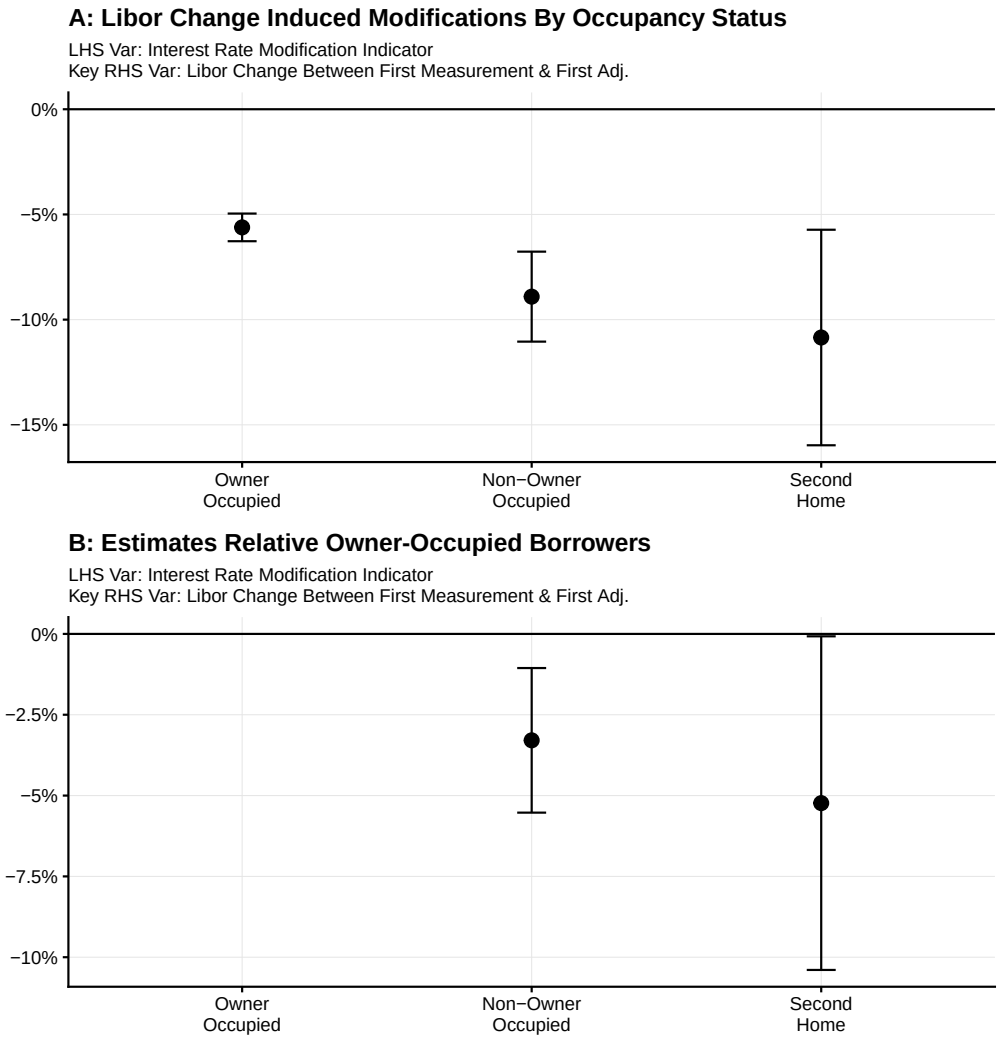


Figure 3: First Stage and 2SLS Estimates – Libor Change-Induced Modifications



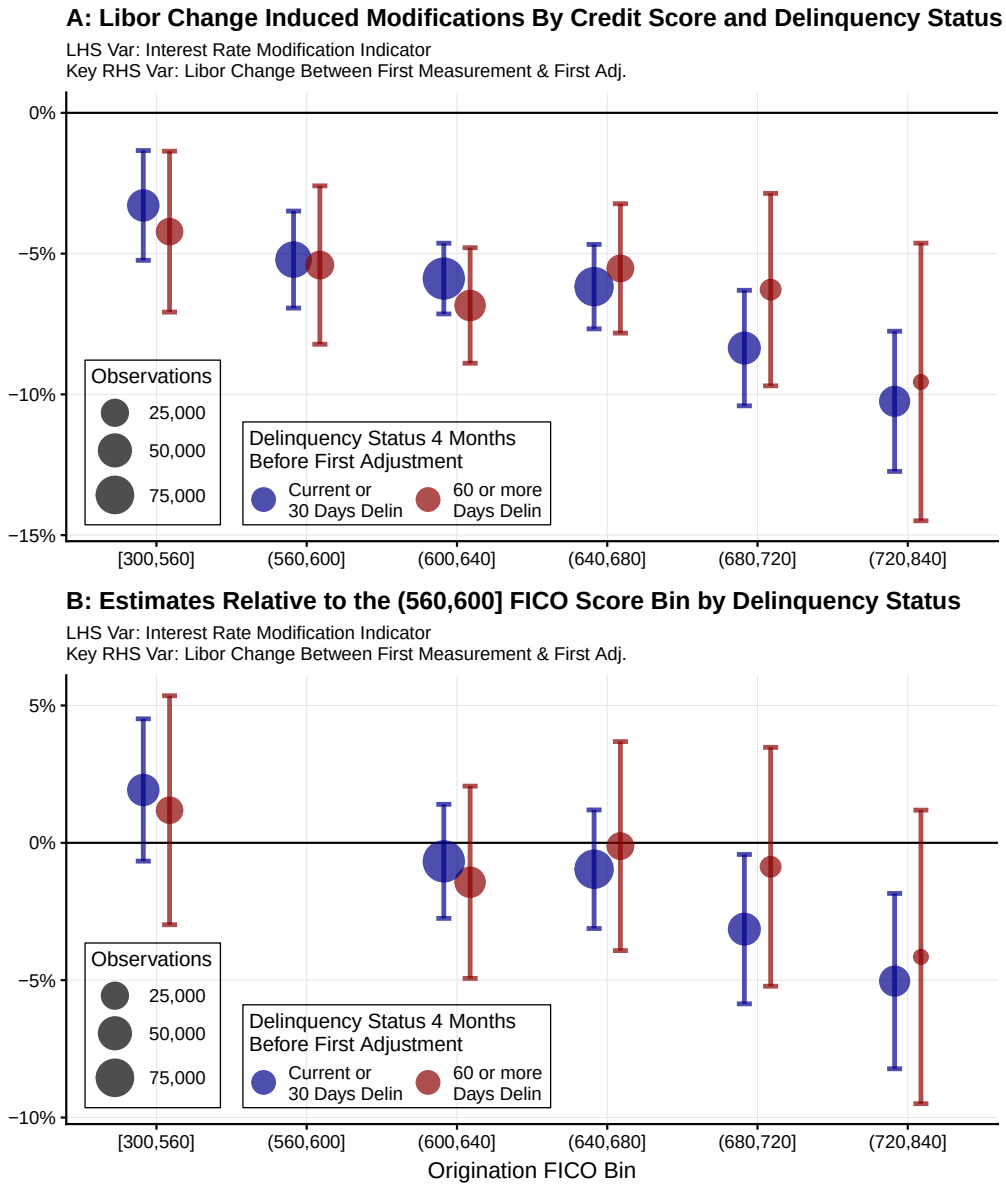
Notes: Confidence bands are based on ±2.5 robust standard errors clustered at the three-digit zip code level. Controls are listed in footnote 19.

Figure 4: First Stage Estimates by Owner Occupancy Status



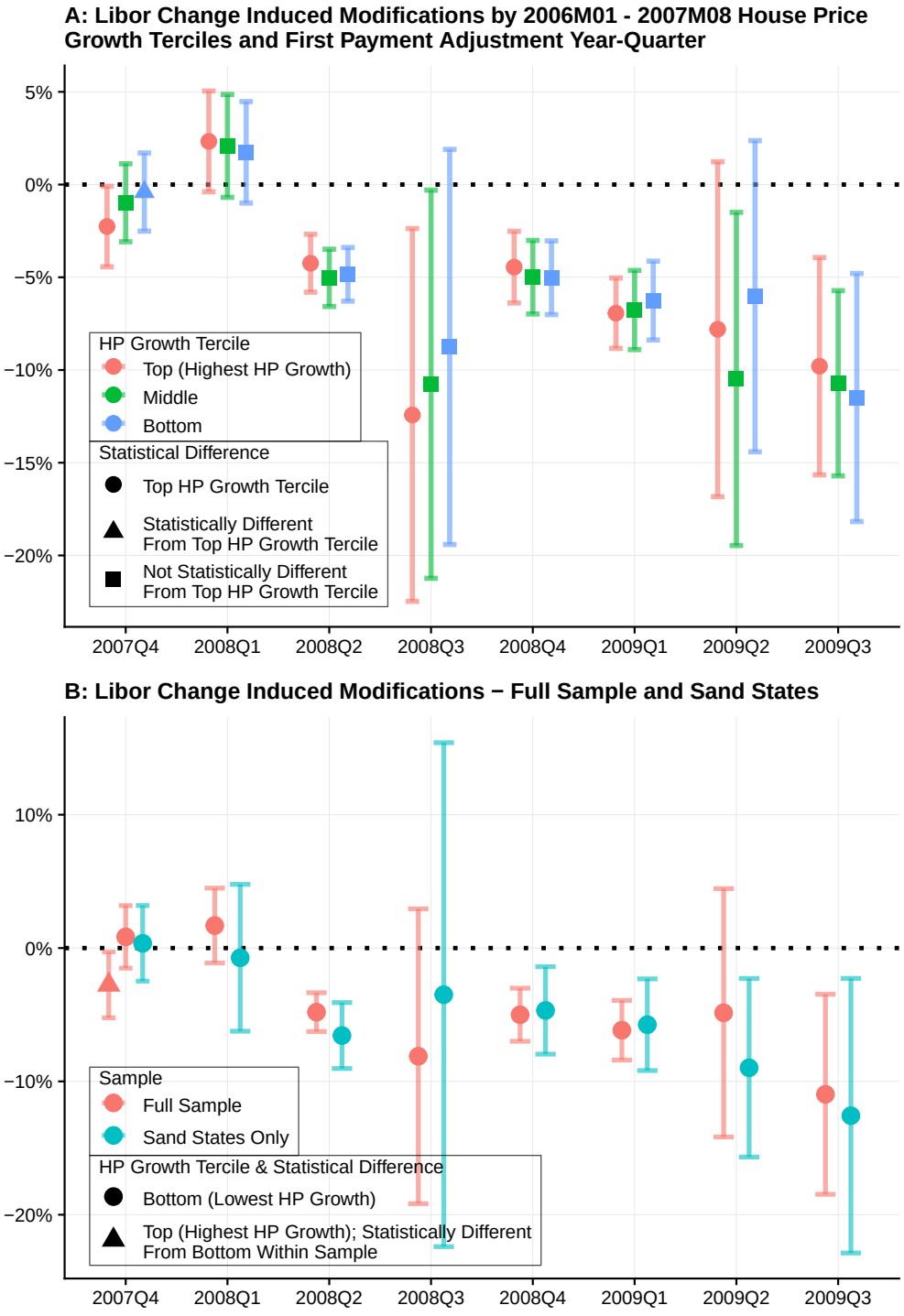
Notes: Confidence bands are based on ±2.5 robust standard errors clustered at the three-digit zip code level. Controls are listed in footnote 19.

Figure 5: First Stage Estimates by FICO Score Bins and Delinquency Status



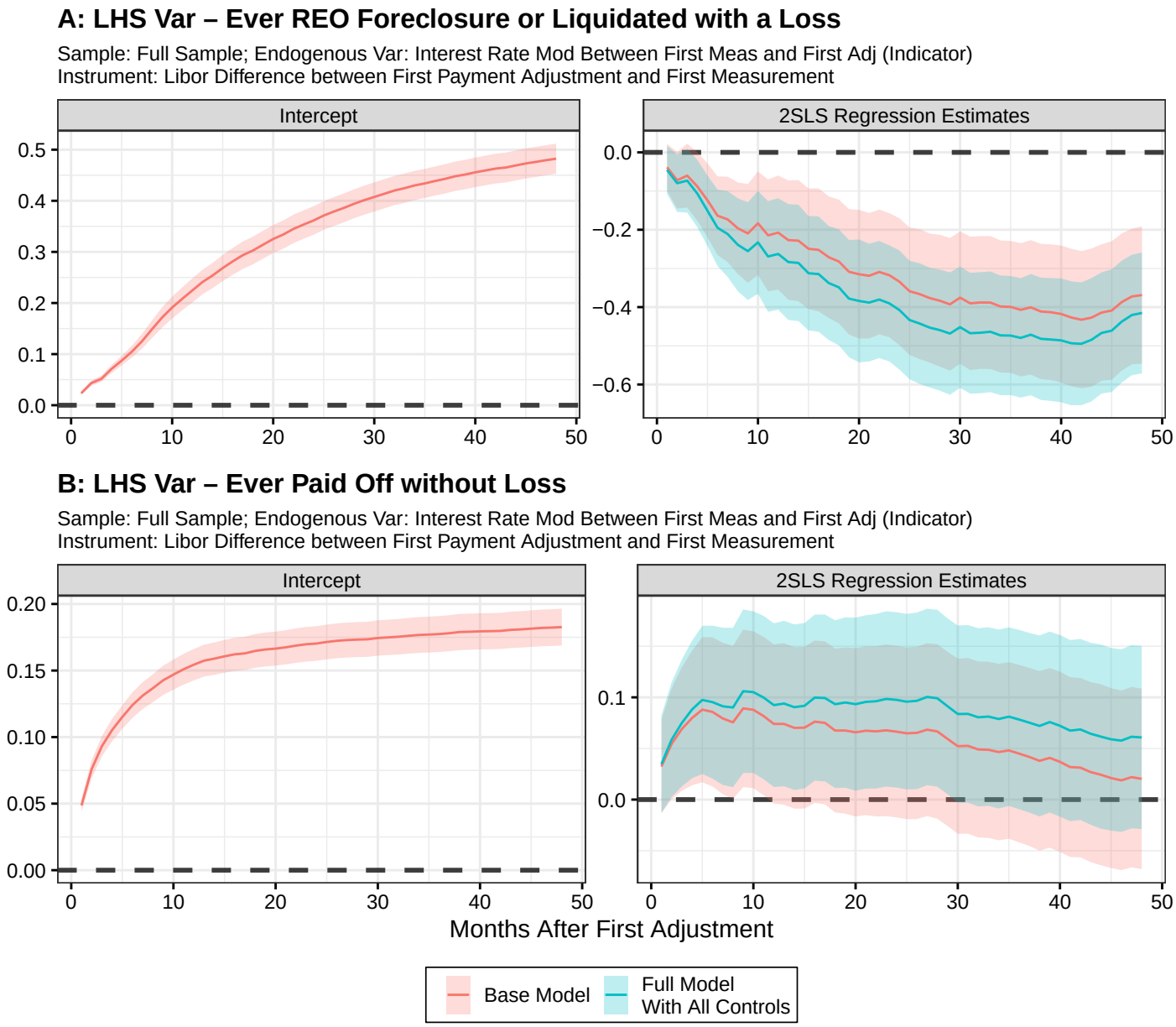
Notes: Confidence bands are based on ±2.5 robust standard errors clustered at the three-digit zip code level. Controls are listed in footnote 19.

Figure 6: Libor Change-Induced Modifications Across Geographic Submarkets



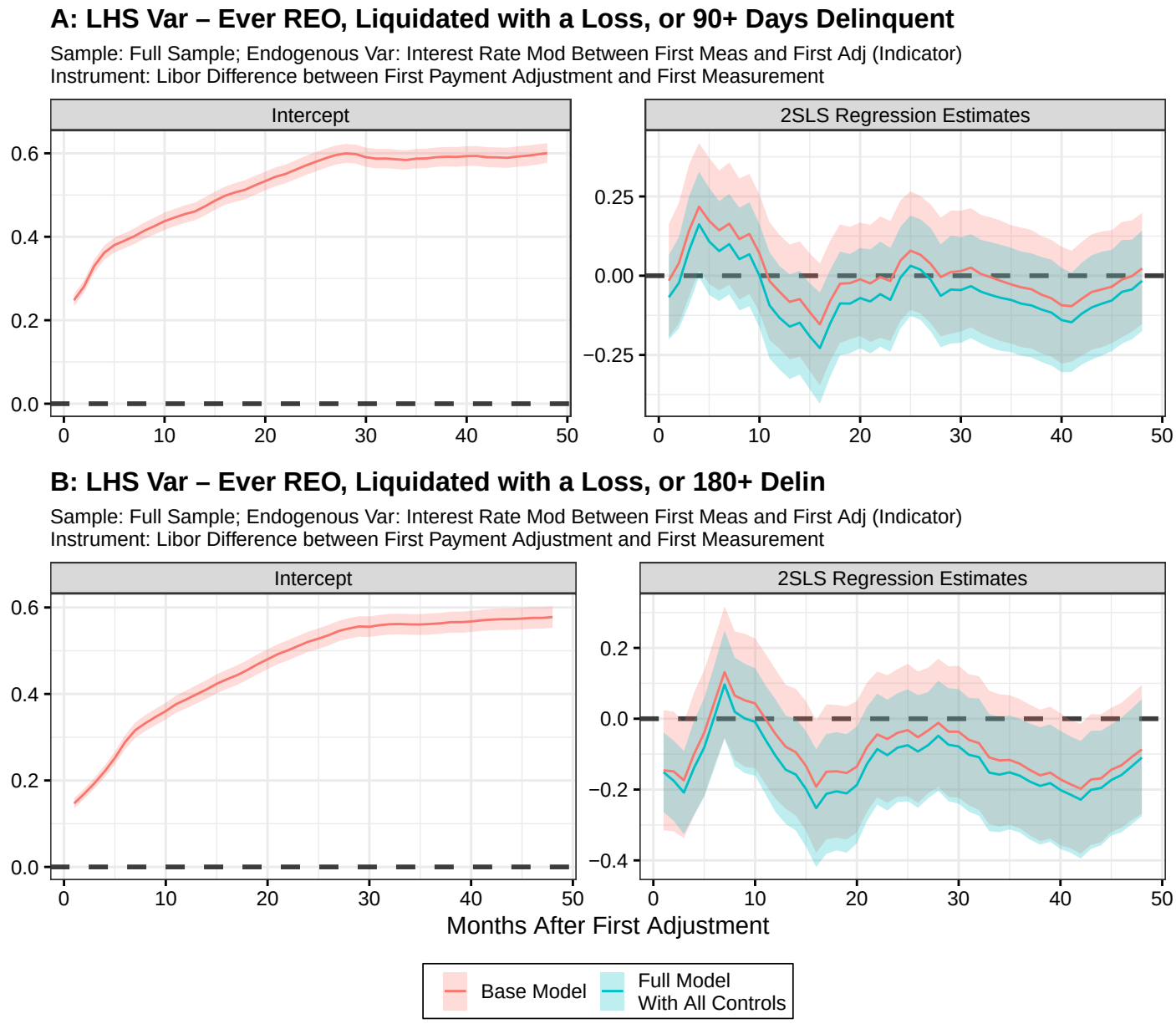
Notes: Confidence bands are based on ±2.5 robust standard errors clustered at the three-digit zip code level. Controls are listed in footnote 19.

Figure 7: The Dynamic Impact of Libor Change-Induced Modifications on Foreclosures and Repayments



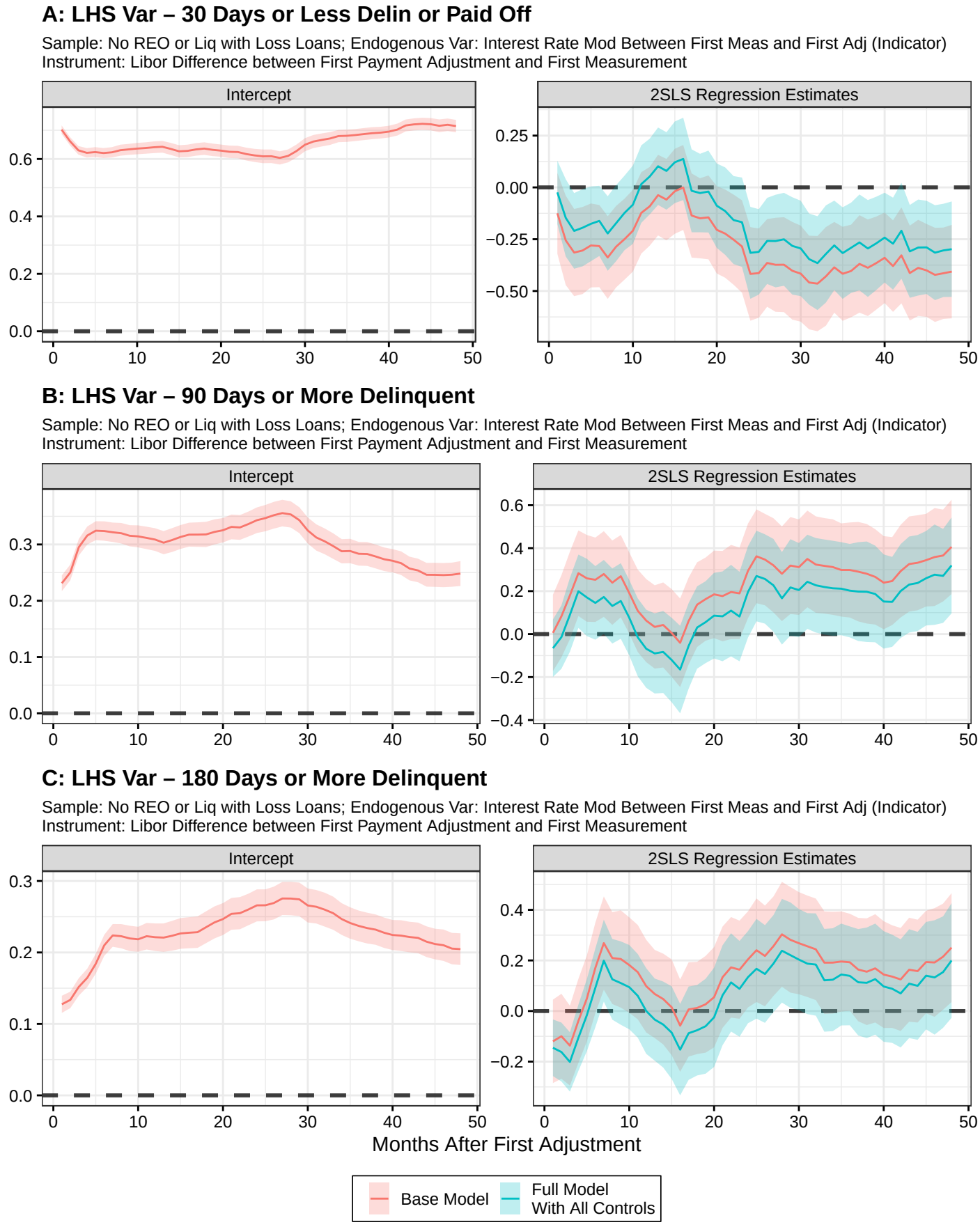
Notes: Red lines use a baseline set of controls described in section 5.5. Green lines use a full set of controls listed in footnote 19. Confidence bands are based on ±2.5 robust standard errors clustered at the three-digit zip code level.

Figure 8: The Dynamic Impact of Libor Change-Induced Modifications on Foreclosures and Defaults



Notes: Red lines use a baseline set of controls described in section 5.5. Green lines use a full set of controls listed in footnote 19. Confidence bands are based on ±2.5 robust standard errors clustered at the three-digit zip code level.

Figure 9: The Dynamic Impact of Libor Change-Induced Modifications on Loans that Never Entered REO Foreclosure or were Never Liquidated with a Loss



Notes: Red lines use a baseline set of controls described in section 5.5. Green lines use a full set of controls listed in footnote 19. Confidence bands are based on ±2.5 robust standard errors clustered at the three-digit zip code level.

A Appendix: Using An Interest Rate Decline of 0.5 Percentage Points as the Modification Threshold

Table A1: Regression Estimates at First Payment Adjustment – Using 0.5 Percentage Points as the Modification Threshold

	Dependent variable:				
	At First Adj.			6-months After First Adj.	
	ln(Rate Paymt), First Adj. − Meas.	Rate Paymt $, First Adj. − Meas.	ΔDTI, Back-End (SDs)	Int Rate, 6m Post Adj. − First Adj.	Ever REO or Liq with Loss
	(1)	(2)	(3)	(4)	(5)
Panel A: 2SLS Estimates					
Modification Indicator	−0.2077	−337.1666	−0.1486	−0.4408	−0.1366
	(0.0080)	(18.1295)	(0.0645)	(0.1521)	(0.0275)
First Stage Coef on Libor Diff IV	−0.078	−0.078	−0.084	−0.078	−0.078
First Stage F-stat	542.03	542.03	655.55	542.03	542.03
Panel B: Reduced Form					
Libor Diff Between First Meas & Adj.	0.0162	26.3498	0.0124	0.0344	0.0107
	(0.0008)	(1.6156)	(0.0054)	(0.0114)	(0.0021)
Panel C: OLS Estimates					
Modification Indicator	−0.1930	−265.3508	−0.0358	0.8580	−0.0420
	(0.0013)	(7.5373)	(0.0043)	(0.0092)	(0.0025)
Observations	350,440	350,440	326,434	350,440	350,440
Controls	✓	✓	✓	✓	✓

Notes: Regression estimates around first payment adjustment. Controls are listed in footnote 19.

Table A2: Regression Estimates 48 Months After First Adjustment – Using 0.5 Percentage Points as the Modification Threshold

	Dependent variable:						
	All Loans				Never REO or Loss After 48 Months		
	Ever REO or Loss	Ever Paid Off	Ever REO or Loss, or Is Delin90+	Ever REO or Loss, or Is Delin180+	Is Delin $\leq$ 30 or Ever Paid Off	Is Delin90+	Is Delin180+
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: 2SLS Estimates							
Modification Indicator	−0.2911	0.0426	−0.0113	−0.0771	−0.2097	0.2248	0.1404
	(0.0425)	(0.0252)	(0.0444)	(0.0463)	(0.0641)	(0.0619)	(0.0637)
First Stage Coef on Libor Diff IV	−0.078	−0.078	−0.078	−0.078	−0.076	−0.076	−0.076
First Stage F-stat	542.03	542.03	544.51	544.51	308.77	308.77	308.77
Panel B: Reduced Form							
Libor Diff Between First Meas & Adj.	0.0227	−0.0033	0.0009	0.0060	0.0159	−0.0171	−0.0107
	(0.0034)	(0.0020)	(0.0035)	(0.0037)	(0.0047)	(0.0045)	(0.0047)
Panel C: OLS Estimates							
Modification Indicator	−0.0277	−0.0096	−0.0292	−0.0340	0.0318	−0.0357	−0.0412
	(0.0025)	(0.0013)	(0.0026)	(0.0027)	(0.0036)	(0.0035)	(0.0034)
Observations	350,440	350,440	350,050	350,050	210,526	210,526	210,526
Controls	✓	✓	✓	✓	✓	✓	✓

Notes: Regression estimates 48 months after first payment adjustment. Controls are listed in footnote 19.

B Appendix: Jackknife Estimator – First Stage and 2SLS Estimates

Table B1: Regression Estimates at First Payment Adjustment Using a Jackknife Estimator

	Dependent variable:				
	At First Adj.			6-months After First Adj.	
	ln(Rate Paymt), First Adj. − Meas.	Rate Paymt $, First Adj. − Meas.	ΔDTI, Back-End (SDs)	Int Rate, 6m Post Adj. − First Adj.	Ever REO or Liq with Loss
	(1)	(2)	(3)	(4)	(5)
Panel A: 2SLS Estimates					
Modification Indicator	−0.2881	−445.5741	−0.2949	−0.4825	−0.2223
	(0.0116)	(22.7683)	(0.0992)	(0.2316)	(0.0424)
First Stage Coef on Libor Diff IV	0.054	0.054	0.058	0.054	0.054
First Stage F-stat	352.66	352.66	389.97	352.66	352.66
Panel B: Reduced Form					
Libor Diff Between First Meas & Adj.	−0.0155	−24.0451	−0.0173	−0.0260	−0.0120
	(0.0008)	(1.5377)	(0.0058)	(0.0119)	(0.0023)
Panel C: OLS Estimates					
Modification Indicator	−0.2156	−293.6072	−0.0436	0.9427	−0.0457
	(0.0015)	(8.1677)	(0.0049)	(0.0095)	(0.0027)
Observations	350,440	350,440	326,434	350,440	350,440
Controls	✓	✓	✓	✓	✓

Notes: Regression estimates around first payment adjustment. Controls are listed in footnote 19. The instrument is computed using a jackknife estimator to capture lookback period × reset month variation.

Table B2: Regression Estimates 48 Months After First Adjustment Using a Jackknife Estimator

	Dependent variable:						
	All Loans				Never REO or Loss After 48 Months		
	Ever REO or Loss	Ever Paid Off	Ever REO or Loss, or Is Delin90+	Ever REO or Loss, or Is Delin180+	Is Delin $\leq$ 30 or Ever Paid Off	Is Delin90+	Is Delin180+
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: 2SLS Estimates							
Modification Indicator	−0.5100	0.0716	−0.0136	−0.1159	−0.3788	0.3881	0.2629
	(0.0676)	(0.0392)	(0.0695)	(0.0720)	(0.0981)	(0.0939)	(0.0954)
First Stage Coef on Libor Diff IV	0.054	0.054	0.054	0.054	0.054	0.054	0.054
First Stage F-stat	352.66	352.66	354.48	354.48	206.49	206.49	206.49
Panel B: Reduced Form							
Libor Diff Between First Meas & Adj.	−0.0275	0.0039	−0.0007	−0.0063	−0.0204	0.0209	0.0142
	(0.0035)	(0.0021)	(0.0038)	(0.0039)	(0.0051)	(0.0048)	(0.0050)
Panel C: OLS Estimates							
Modification Indicator	−0.0279	−0.0076	−0.0279	−0.0325	0.0324	−0.0357	−0.0409
	(0.0029)	(0.0014)	(0.0029)	(0.0030)	(0.0040)	(0.0038)	(0.0038)
Observations	350,440	350,440	350,050	350,050	210,526	210,526	210,526
Controls	✓	✓	✓	✓	✓	✓	✓

Notes: Regression estimates 48 months after first payment adjustment. Controls are listed in footnote 19. The instrument is computed using a jackknife estimator to capture lookback period × reset month variation.

C Appendix: Non-Current Loans – First Stage and 2SLS Estimates

Table C1: Regression Estimates at First Payment Adjustment – Borrowers Not Current 4 months Before First Adjustment

	Dependent variable:				
	At First Adj.			6-months After First Adj.	
	ln(Rate Paymt), First Adj. − Meas.	Rate Paymt $, First Adj. − Meas.	ΔDTI, Back-End (SDs)	Int Rate, 6m Post Adj. − First Adj.	Ever REO or Liq with Loss
	(1)	(2)	(3)	(4)	(5)
Panel A: 2SLS Estimates					
Modification Indicator	−0.3277	−520.0246	−0.2416	−0.8127	−0.3073
	(0.0196)	(34.8498)	(0.1222)	(0.3118)	(0.0744)
First Stage Coef on Libor Diff IV	−0.060	−0.060	−0.068	−0.060	−0.060
First Stage F-stat	196.83	196.83	238.54	196.83	196.83
Panel B: Reduced Form					
Libor Diff Between First Meas & Adj.	0.0195	30.9810	0.0164	0.0484	0.0183
	(0.0014)	(2.3155)	(0.0083)	(0.0172)	(0.0042)
Panel C: OLS Estimates					
Modification Indicator	−0.2552	−347.3565	−0.0360	1.0142	−0.0859
	(0.0020)	(9.6364)	(0.0095)	(0.0111)	(0.0051)
Observations	141,829	141,829	125,994	141,829	141,829
Controls	✓	✓	✓	✓	✓

Notes: Regression estimates around first payment adjustment. Controls are listed in footnote 19.

Table C2: Regression Estimates 48 Months After First Adjustment – Borrowers Not Current 4 months Before First Adjustment

	Dependent variable:						
	All Loans				Never REO or Loss After 48 Months		
	Ever REO or Loss	Ever Paid Off	Ever REO or Loss, or Is Delin90+	Ever REO or Loss, or Is Delin180+	Is Delin $\leq$ 30 or Ever Paid Off	Is Delin90+	Is Delin180+
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: 2SLS Estimates							
Modification Indicator	−0.4941	−0.0133	−0.0853	−0.1841	−0.1750	0.2160	0.0792
	(0.0948)	(0.0235)	(0.0799)	(0.0811)	(0.1508)	(0.1460)	(0.1458)
First Stage Coef on Libor Diff IV	−0.060	−0.060	−0.060	−0.060	−0.057	−0.057	−0.057
First Stage F-stat	196.83	196.83	199.01	199.01	77.03	77.03	77.03
Panel B: Reduced Form							
Libor Diff Between First Meas & Adj.	0.0294	0.0008	0.0051	0.0110	0.0100	−0.0124	−0.0045
	(0.0052)	(0.0014)	(0.0048)	(0.0048)	(0.0085)	(0.0082)	(0.0083)
Panel C: OLS Estimates							
Modification Indicator	−0.0585	0.0020	−0.0554	−0.0620	0.0587	−0.0643	−0.0719
	(0.0042)	(0.0011)	(0.0039)	(0.0040)	(0.0063)	(0.0062)	(0.0062)
Observations	141,829	141,829	141,614	141,614	64,754	64,754	64,754
Controls	✓	✓	✓	✓	✓	✓	✓

Notes: Regression estimates 48 months after first payment adjustment. Controls are listed in footnote 19.

D Appendix: Current Loans – First Stage and 2SLS Estimates

Table D1: Regression Estimates at First Payment Adjustment – Borrowers Current 4 months Before First Adjustment

	Dependent variable:				
	At First Adj.			6-months After First Adj.	
	ln(Rate Paymt), First Adj. – Meas.	Rate Paymt $, First Adj. – Meas.	ΔDTI, Back-End (SDs)	Int Rate, 6m Post Adj. – First Adj.	Ever REO or Liq with Loss
	(1)	(2)	(3)	(4)	(5)
Panel A: 2SLS Estimates					
Modification Indicator	−0.2584	−434.4346	−0.1862	−0.5925	−0.0402
	(0.0124)	(29.8807)	(0.1358)	(0.3160)	(0.0348)
First Stage Coef on Libor Diff IV	−0.049	−0.049	−0.050	−0.049	−0.049
First Stage F-stat	161.87	161.87	160.83	161.87	161.87
Panel B: Reduced Form					
Libor Diff Between First Meas & Adj.	0.0126	21.1446	0.0092	0.0288	0.0020
	(0.0009)	(1.8114)	(0.0068)	(0.0146)	(0.0017)
Panel C: OLS Estimates					
Modification Indicator	−0.1785	−244.6606	−0.0614	0.8957	0.0011
	(0.0014)	(7.2065)	(0.0052)	(0.0123)	(0.0014)
Observations	208,611	208,611	200,440	208,611	208,611
Controls	✓	✓	✓	✓	✓

Notes: Regression estimates around first payment adjustment. Controls are listed in footnote 19.

Table D2: Regression Estimates 48 Months After First Adjustment – Borrowers Current 4 months Before First Adjustment

	Dependent variable:						
	All Loans				Never REO or Loss After 48 Months		
	Ever REO or Loss	Ever Paid Off	Ever REO or Loss, or Is Delin90+	Ever REO or Loss, or Is Delin180+	Is Delin $\leq$ 30 or Ever Paid Off	Is Delin90+	Is Delin180+
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: 2SLS Estimates							
Modification Indicator	−0.2988	0.1081	0.0667	−0.0277	−0.3740	0.3809	0.2638
	(0.0948)	(0.0702)	(0.1062)	(0.1092)	(0.1220)	(0.1163)	(0.1156)
First Stage Coef on Libor Diff IV	−0.049	−0.049	−0.049	−0.049	−0.049	−0.049	−0.049
First Stage F-stat	161.87	161.87	161.98	161.98	119.06	119.06	119.06
Panel B: Reduced Form							
Libor Diff Between First Meas & Adj.	0.0145	−0.0053	−0.0033	0.0014	0.0182	−0.0185	−0.0128
	(0.0046)	(0.0034)	(0.0051)	(0.0053)	(0.0057)	(0.0054)	(0.0055)
Panel C: OLS Estimates							
Modification Indicator	0.0008	−0.0153	−0.0082	−0.0101	0.0114	−0.0126	−0.0159
	(0.0038)	(0.0025)	(0.0041)	(0.0043)	(0.0049)	(0.0046)	(0.0045)
Observations	208,611	208,611	208,436	208,436	145,772	145,772	145,772
Controls	✓	✓	✓	✓	✓	✓	✓

Notes: Regression estimates 48 months after first payment adjustment. Controls are listed in footnote 19.

E Appendix: Sand State Loans – First Stage and 2SLS Estimates

Table E1: Regression Estimates at First Payment Adjustment – Sand States

	Dependent variable:				
	At First Adj.			6-months After First Adj.	
	ln(Rate Paymt), First Adj. − Meas.	Rate Paymt $, First Adj. − Meas.	ΔDTI, Back-End (SDs)	Int Rate, 6m Post Adj. − First Adj.	Ever REO or Liq with Loss
	(1)	(2)	(3)	(4)	(5)
Panel A: 2SLS Estimates					
Modification Indicator	−0.3074	−589.3883	−0.3790	−0.8962	−0.2199
	(0.0181)	(45.7226)	(0.1467)	(0.3667)	(0.0699)
First Stage Coef on Libor Diff IV	−0.059	−0.059	−0.064	−0.059	−0.059
First Stage F-stat	129.45	129.45	138.92	129.45	129.45
Panel B: Reduced Form					
Libor Diff Between First Meas & Adj.	0.0183	35.0062	0.0241	0.0532	0.0131
	(0.0013)	(3.0235)	(0.0093)	(0.0194)	(0.0040)
Panel C: OLS Estimates					
Modification Indicator	−0.2277	−370.6039	−0.0422	0.9206	−0.0614
	(0.0019)	(13.8689)	(0.0071)	(0.0107)	(0.0050)
Observations	121,776	121,776	113,410	121,776	121,776
Controls	✓	✓	✓	✓	✓

Notes: Regression estimates around first payment adjustment. Controls are listed in footnote 19.

Table E2: Regression Estimates 48 Months After First Adjustment – Sand States

	Dependent variable:						
	All Loans				Never REO or Loss After 48 Months		
	Ever REO or Loss	Ever Paid Off	Ever REO or Loss, or Is Delin90+	Ever REO or Loss, or Is Delin180+	Is Delin $\leq$ 30 or Ever Paid Off	Is Delin90+	Is Delin180+
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: 2SLS Estimates							
Modification Indicator	−0.3269	0.0281	0.0259	−0.0403	−0.3882	0.3268	0.2314
	(0.0901)	(0.0320)	(0.0859)	(0.0921)	(0.1572)	(0.1528)	(0.1738)
First Stage Coef on Libor Diff IV	−0.059	−0.059	−0.060	−0.060	−0.056	−0.056	−0.056
First Stage F-stat	129.45	129.45	129.76	129.76	77.71	77.71	77.71
Panel B: Reduced Form							
Libor Diff Between First Meas & Adj.	0.0194	−0.0017	−0.0015	0.0024	0.0217	−0.0183	−0.0130
	(0.0054)	(0.0019)	(0.0051)	(0.0055)	(0.0081)	(0.0079)	(0.0093)
Panel C: OLS Estimates							
Modification Indicator	−0.0294	−0.0069	−0.0297	−0.0342	0.0369	−0.0444	−0.0512
	(0.0041)	(0.0014)	(0.0038)	(0.0041)	(0.0070)	(0.0069)	(0.0070)
Observations	121,776	121,776	121,574	121,574	56,779	56,779	56,779
Controls	✓	✓	✓	✓	✓	✓	✓

Notes: Regression estimates 48 months after first payment adjustment. Controls are listed in footnote 19.

F Appendix: Non-Sand Sates Loans – First Stage and 2SLS Estimates

Table F1: Regression Estimates at First Payment Adjustment – Non-Sand States

	Dependent variable:				
	At First Adj.			6-months After First Adj.	
	ln(Rate Paymt), First Adj. − Meas.	Rate Paymt $, First Adj. − Meas.	ΔDTI, Back-End (SDs)	Int Rate, 6m Post Adj. − First Adj.	Ever REO or Liq with Loss
	(1)	(2)	(3)	(4)	(5)
Panel A: 2SLS Estimates					
Modification Indicator	−0.2860	−397.6349	−0.0816	−0.3680	−0.1493
	(0.0144)	(25.5557)	(0.1223)	(0.2816)	(0.0479)
First Stage Coef on Libor Diff IV	−0.052	−0.052	−0.056	−0.052	−0.052
First Stage F-stat	207.55	207.55	228.00	207.55	207.55
Panel B: Reduced Form					
Libor Diff Between First Meas & Adj.	0.0149	20.6507	0.0046	0.0191	0.0078
	(0.0011)	(1.7583)	(0.0068)	(0.0141)	(0.0025)
Panel C: OLS Estimates					
Modification Indicator	−0.2081	−245.3866	−0.0478	0.9684	−0.0343
	(0.0019)	(8.2309)	(0.0067)	(0.0133)	(0.0022)
Observations	228,664	228,664	213,024	228,664	228,664
Controls	✓	✓	✓	✓	✓

Notes: Regression estimates around first payment adjustment. Controls are listed in footnote 19.

Table F2: Regression Estimates 48 Months After First Adjustment – Non-Sand States

	Dependent variable:						
	All Loans				Never REO or Loss After 48 Months		
	Ever REO or Loss	Ever Paid Off	Ever REO or Loss, or Is Delin90+	Ever REO or Loss, or Is Delin180+	Is Delin $\leq$ 30 or Ever Paid Off	Is Delin90+	Is Delin180+
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: 2SLS Estimates							
Modification Indicator	−0.4074	0.0213	0.0139	−0.0990	−0.2697	0.3280	0.2004
	(0.0869)	(0.0580)	(0.0901)	(0.0931)	(0.1123)	(0.1092)	(0.1038)
First Stage Coef on Libor Diff IV	−0.052	−0.052	−0.052	−0.052	−0.053	−0.053	−0.053
First Stage F-stat	207.55	207.55	208.19	208.19	127.61	127.61	127.61
Panel B: Reduced Form							
Libor Diff Between First Meas & Adj.	0.0212	−0.0011	−0.0007	0.0052	0.0142	−0.0173	−0.0105
	(0.0044)	(0.0030)	(0.0047)	(0.0048)	(0.0058)	(0.0055)	(0.0054)
Panel C: OLS Estimates							
Modification Indicator	−0.0275	−0.0066	−0.0286	−0.0332	0.0293	−0.0307	−0.0355
	(0.0039)	(0.0020)	(0.0040)	(0.0042)	(0.0049)	(0.0046)	(0.0046)
Observations	228,664	228,664	228,476	228,476	153,747	153,747	153,747
Controls	✓	✓	✓	✓	✓	✓	✓

Notes: Regression estimates 48 months after first payment adjustment. Controls are listed in footnote 19.

G Appendix: Non-subprime, Current Loans in Positive Pre-Treatment House Price Growth Zip Codes – First Stage and 2SLS Estimates

Table G1: Regression Estimates at First Payment Adjustment – Prime, Current Loans, in Zip Codes with Positive House Price Growth from 2006M01 - 2007M08

	Dependent variable:				
	At First Adj.			6-months After First Adj.	
	ln(Rate Paymt), First Adj. – Meas.	Rate Paymt $, First Adj. – Meas.	ΔDTI, Back-End (SDs)	Int Rate, 6m Post Adj. – First Adj.	Ever REO or Liq with Loss
	(1)	(2)	(3)	(4)	(5)
Panel A: 2SLS Estimates					
Modification Indicator	−0.3034	−342.7064	−0.0766	−0.3423	0.0254
	(0.0143)	(24.2382)	(0.1417)	(0.3055)	(0.0443)
First Stage Coef on Libor Diff IV	−0.080	−0.080	−0.085	−0.080	−0.080
First Stage F-stat	119.61	119.61	124.51	119.61	119.61
Panel B: Reduced Form					
Libor Diff Between First Meas & Adj.	0.0244	27.5763	0.0065	0.0275	−0.0020
	(0.0019)	(2.6060)	(0.0120)	(0.0236)	(0.0036)
Panel C: OLS Estimates					
Modification Indicator	−0.2024	−260.6361	−0.0375	0.6168	−0.0010
	(0.0040)	(11.7774)	(0.0120)	(0.0246)	(0.0036)
Observations	49,104	49,104	46,640	49,104	49,104
Controls	✓	✓	✓	✓	✓

Notes: Regression estimates around first payment adjustment. Controls are listed in footnote 19.

Table G2: Regression Estimates 48 Months After First Adjustment – Prime, Current Loans, in Zip Codes with Positive House Price Growth from 2006M01 - 2007M08

	Dependent variable:						
	All Loans				Never REO or Loss After 48 Months		
	Ever REO or Loss	Ever Paid Off	Ever REO or Loss, or Is Delin90+	Ever REO or Loss, or Is Delin180+	Is Delin $\leq$ 30 or Ever Paid Off	Is Delin90+	Is Delin180+
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: 2SLS Estimates							
Modification Indicator	−0.2035	0.0284	−0.2752	−0.2204	0.1412	−0.1826	−0.1067
	(0.1175)	(0.0911)	(0.1267)	(0.1203)	(0.1264)	(0.1292)	(0.1149)
First Stage Coef on Libor Diff IV	−0.080	−0.080	−0.081	−0.081	−0.084	−0.084	−0.084
First Stage F-stat	119.61	119.61	120.45	120.45	85.41	85.41	85.41
Panel B: Reduced Form							
Libor Diff Between First Meas & Adj.	0.0164	−0.0023	0.0222	0.0178	−0.0118	0.0153	0.0089
	(0.0095)	(0.0073)	(0.0105)	(0.0100)	(0.0107)	(0.0109)	(0.0097)
Panel C: OLS Estimates							
Modification Indicator	−0.0157	−0.0368	−0.0362	−0.0371	0.0317	−0.0331	−0.0334
	(0.0101)	(0.0071)	(0.0105)	(0.0098)	(0.0120)	(0.0110)	(0.0098)
Observations	49,104	49,104	49,025	49,025	36,367	36,367	36,367
Controls	✓	✓	✓	✓	✓	✓	✓

Notes: Regression estimates 48 months after first payment adjustment. Controls are listed in footnote 19.

H Appendix: Non-Owner-Occupied Borrowers – First Stage and 2SLS Estimates

Table G1: Regression Estimates at First Payment Adjustment for Non-Owner Occupied Borrowers

	Dependent variable:				
	At First Adj.			6-months After First Adj.	
	ln(Rate Paymt), First Adj. − Meas.	Rate Paymt $, First Adj. − Meas.	ΔDTI, Back-End (SDs)	Int Rate, 6m Post Adj. − First Adj.	Ever REO or Liq with Loss
	(1)	(2)	(3)	(4)	(5)
Panel A: 2SLS Estimates					
Modification Indicator	−0.2831	−330.1308	−0.3868	−1.1479	0.0012
	(0.0325)	(46.3696)	(0.2571)	(0.6603)	(0.1643)
First Stage Coef on Libor Diff IV	−0.066	−0.066	−0.073	−0.066	−0.066
First Stage F-stat	37.93	37.93	44.08	37.93	37.93
Panel B: Reduced Form					
Libor Diff Between First Meas & Adj.	0.0187	21.8107	0.0281	0.0758	−0.0001
	(0.0031)	(3.7541)	(0.0186)	(0.0389)	(0.0109)
Panel C: OLS Estimates					
Modification Indicator	−0.2212	−241.8632	0.0113	0.8060	−0.0604
	(0.0088)	(13.7364)	(0.0265)	(0.0582)	(0.0139)
Observations	16,451	16,451	15,406	16,451	16,451
Controls	✓	✓	✓	✓	✓

Notes: Regression estimates around first payment adjustment. Controls are listed in footnote 19.

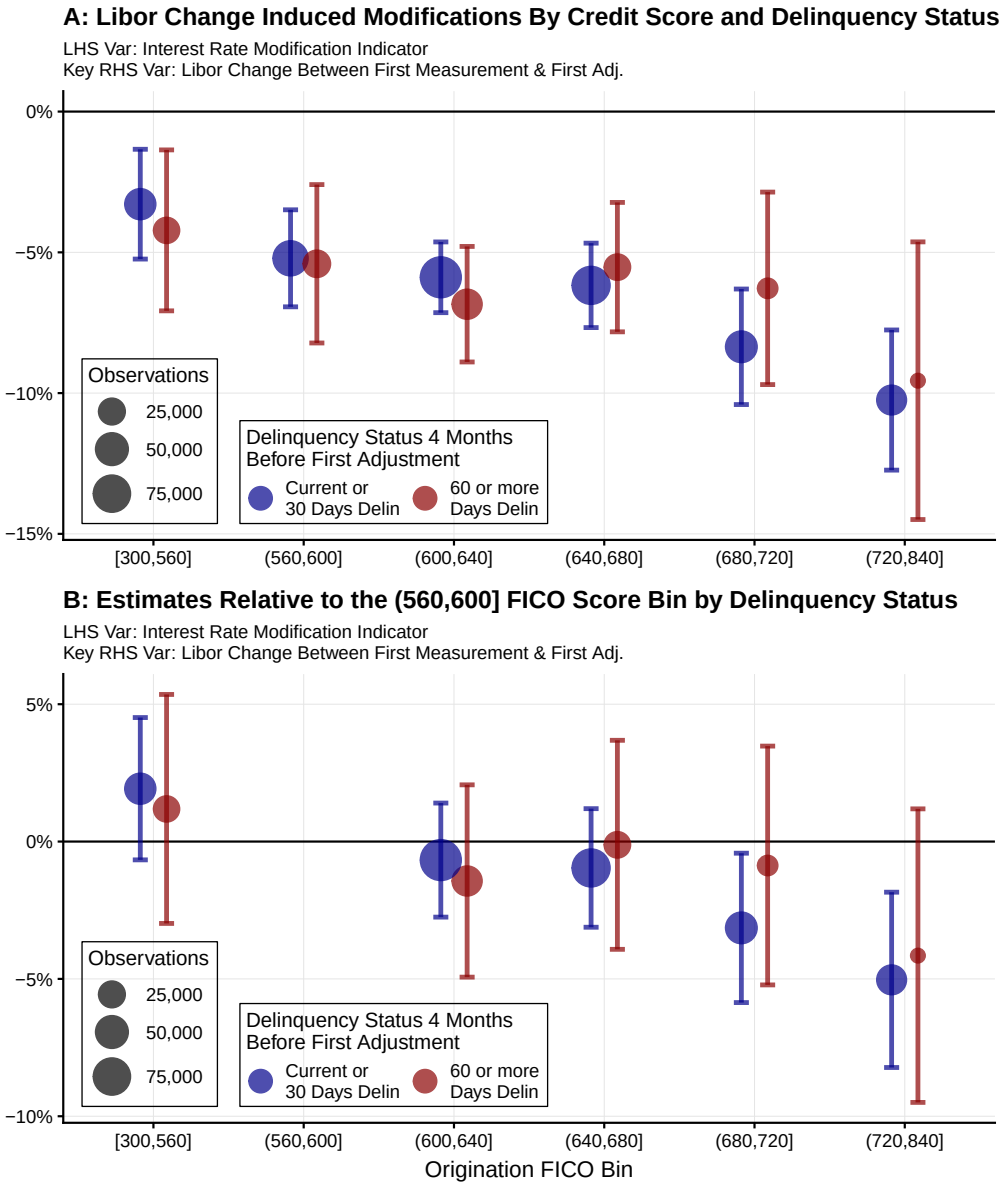
Table G2: Regression Estimates 48 Months After First Adjustment for Non-Owner-Occupied Borrowers

	Dependent variable:						
	All Loans				Never REO or Loss After 48 Months		
	Ever REO or Loss	Ever Paid Off	Ever REO or Loss, or Is Delin90+	Ever REO or Loss, or Is Delin180+	Is Delin $\leq$ 30 or Ever Paid Off	Is Delin90+	Is Delin180+
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: 2SLS Estimates							
Modification Indicator	−0.0763	−0.3101	−0.0864	0.0002	−0.3104	0.2174	0.4304
	(0.2399)	(0.1265)	(0.2163)	(0.2274)	(0.4462)	(0.4363)	(0.4377)
First Stage Coef on Libor Diff IV	−0.066	−0.066	−0.066	−0.066	−0.052	−0.052	−0.052
First Stage F-stat	37.93	37.93	37.94	37.94	15.37	15.37	15.37
Panel B: Reduced Form							
Libor Diff Between First Meas & Adj.	0.0050	0.0205	0.0057	−0.00001	0.0163	−0.0114	−0.0226
	(0.0158)	(0.0077)	(0.0143)	(0.0151)	(0.0231)	(0.0226)	(0.0216)
Panel C: OLS Estimates							
Modification Indicator	−0.0771	−0.0050	−0.0495	−0.0544	0.0292	−0.0189	−0.0244
	(0.0193)	(0.0092)	(0.0202)	(0.0200)	(0.0296)	(0.0292)	(0.0272)
Observations	16,451	16,451	16,417	16,417	7,789	7,789	7,789
Controls	✓	✓	✓	✓	✓	✓	✓

Notes: Regression estimates 48 months after first payment adjustment. Controls are listed in footnote 19.

I Appendix: First Stage Estimates by FICO Score Bins and Delinquency Status – Using 90 days as the Delinquency Threshold

Figure I1: First Stage Estimates by FICO Score Bins and Delinquency Status – Using 90 days as the Delinquency Threshold



Notes: Confidence bands correspond to ±2.5 robust standard errors clustered at the three-digit zip code level. Controls are listed in footnote 19.