Federal Reserve Bank of Philadelphia

Working Papers
Research Department

WP 18-26
November 2018
https://doi.org/10.21799/frbp.wp.2018.26

Redefault Risk in the Aftermath of the Mortgage Crisis: Why Did Modifications Improve More Than Self-Cures?

Paul Calem
Federal Reserve Bank of Philadelphia Supervision, Regulation, and Credit

Julapa Jagtiani
Federal Reserve Bank of Philadelphia Supervision, Regulation, and Credit

Raman Maingi
Federal Reserve Bank of Philadelphia Supervision, Regulation, and Credit

Consumer Finance Institute

ISSN: 1962-5361

Redefault Risk in the Aftermath of the Mortgage Crisis: Why Did Modifications Improve More Than Self-Cures?

Paul Calem, Julapa Jagtiani, and Raman Maingi *

Federal Reserve Bank of Philadelphia
Supervision, Regulation, and Credit

November 2018

Abstract

This paper examines changes in the redefault rate of mortgages that were selected for modification during 2008–2011, compared with that of similarly situated self-cured mortgages. We find a large decline in the redefault rate of both modified and self-cured mortgages over this period, but the improvement was greatest for modifications. Our analysis has identified several important factors contributing to the greater improvement for modified loans, including an increasing share of principal-reduction modifications, which appear to be more effective than other types of modification and increasingly generous modification terms (larger payment reductions). The favorable impacts of principal and payment reductions on household finances were enhanced by improving economic conditions, resulting in more effective modifications. Even after accounting for these factors, we still observe a larger decline in the redefault rate for modifications compared with similarly situated self-cured loans. This residual effect may reflect servicer "learning-by-doing"; that is, servicers gained knowledge as modification activity ramped up, resulting in more successful modification programs for later cohorts.

Keywords: mortgage modification, mortgage default, mortgage servicing
JEL Codes: G21, G28, G40

---

* Please direct correspondence to Paul Calem, Federal Reserve Bank of Philadelphia, Supervision, Regulation, and Credit Department, Ten Independence Mall, Philadelphia, PA 19106; 215-574-4132; email paul.calem@phil.frb.org. The authors thank Charlie Calomiris, Robert Eisenbeis, Emily Ross, and participants at the IAES (International Atlantic Economic Society) and EFMA (European Financial Management Association) conferences and the Risk Quantification Forum for their helpful comments and suggestions. We also thank David Abell for his contributions to the initial research stages of this paper.

This paper supersedes "Redefault Risk in the Aftermath of the Mortgage Crisis: Why Did Modifications Improve More Than Self-Cures?" by P. Calem, J. Jagtiani, R. Maingi, and D. Abell, Federal Reserve Bank of Philadelphia Working Paper 18-02, January 2018.

1. Introduction

Lenders, or loan servicers acting on their behalf, can choose from several strategic alternatives to resolve a defaulted mortgage, the goal being to maximize its net present value (net of recovery costs). The traditional resolution strategy is a legal foreclosure process, whereby the lender takes possession of the property and puts it up for sale. Lenders may also pursue alternatives to foreclosure that typically provide a shorter path to property liquidation including deed-in-lieu of foreclosure, short sale, or third-party sale.

Alternatively, the lender may modify the loan terms, such as reducing the interest rate, extending the maturity date of the loan, or reducing the principal balance, to facilitate financial relief for borrowers, enabling them to resume their regularly scheduled payments. Mortgage modifications had been used sparingly before the housing market downturn that began in 2008. However, as the downturn worsened through 2008 and 2009 and foreclosures spiked, government programs were launched to encourage modification activity. Lenders, seeking ways to avoid the increased costs associated with foreclosure delays, increasingly relied on modification strategies.

Our study examines payment performance (redefault rates) of first-lien mortgages that received a modification during 2008 through 2011, returning the loan to nondelinquent status and granting a substantial payment reduction. Although previous studies have documented the improving performance of loan modifications over this period, ours is the first study to assess the performance of loan modifications relative to similarly situated self-cured loans. The latter serve as a control for factors that impact the sustainability of cure more generally.

We find that the performance of both modified and self-cured mortgages improved (redefault rates declined) dramatically over this period. However, modified loans' redefault rate declined substantially more than that of similarly situated self-cures. For example, after matching modified to comparable self-cured loans, we find that for agency (Fannie Mae or Freddie Mac) loans, the 36-month cumulative redefault rate of modified loans declined by nearly 75 percent, from slightly above 80 percent to slightly above 20 percent. However, the redefault rate of self-cured agency loans declined only about 50 percent from slightly above 70 percent to about 35 percent.

Our analysis is divided into two parts. First, we develop and implement a procedure for matching loans that were modified from 2008 to 2011 to similarly situated self-cured loans, and we compare how their redefault frequencies evolved over this period. Second, we estimate logistic

regression models of redefault to analyze the factors associated with the steeper decline in redefault rate that we observe for modified loans compared with self-cured loans.

One factor identified in our analysis as an important contributor is the increasing share of principal-reduction modifications, which tend to be more effective than other types of modification — a finding consistent with Goodman, Ashworth, Landy, and Yang (2012). In addition, increasingly generous modification terms (larger payment reductions) was a key contributing factor.

Moreover, the favorable impacts of principal and payment reductions on household finances were enhanced by improving economic conditions over time. In other words, while improved economic conditions also contributed to lower redefault rates for self-cured loans, they had a greater impact when combined with the payment reductions granted through loan modification.

Interestingly, after accounting for these factors, we still observe a larger decline in redefault rates for modified loans compared with similarly situated self-cured loans. A plausible explanation for this residual effect is servicer "learning-by-doing." That is, servicers with limited experience in designing modification programs in 2008 may have gained knowledge as the modification activity ramped up, resulting in more successful modification programs for later vintages.

The paper is organized as follows. Section 2 discusses existing literature related to the use of mortgage modification as a foreclosure alternative as well as the impact of modification on loan performance. Section 3 provides some institutional background for the increase in modification activity and the evolution of modification terms since the onset of the financial crisis in 2008. Section 4 describes the data and our approach to identifying mortgage loans that were modified during the period 2008–2011. In Section 5, we match modified mortgages to similarly situated self-cured mortgages, relying in part on the propensity scoring technique to control for loan risk characteristics. We then compare the cumulative redefault rates of modified loans with their matched self-cures by year of modification or cure. In Section 6, we estimate logistic regression models for redefault, seeking to draw insights into the key factors that drive the larger decline in redefault rates for modified loans. We offer concluding remarks in Section 7.

2. The Literature and Our Contribution

The literature on loan modification roughly separates into two strands: 1) important factors on the borrower (or servicer) side that determine which delinquent loans receive a modification and 2) examination of redefault rate after modification. We are the first to systematically compare

the repayment performance of modifications with that of self-cured loans, such that the matched self-cures function as a control group.

Ability versus willingness to pay. A borrower's default may be caused by an *inability* to make payments or by an *unwillingness* (or lack of incentive) to pay — see, for example, Haughwout, Okah, and Tracy (2009).[1] Past credit payment history (as reflected in a borrower credit score) may reflect an individual's ability to pay insofar as it reflects a vulnerability to income or liquidity shocks; it may also in part reflect a willingness to pay. A lender or servicer's decision on whether to modify and on the modification terms may depend in part on the factors that gave rise to the borrower's default on the mortgage.

Das (2012) develops a theoretical model of an optimal loan modification strategy in a stochastic environment of home prices and interest rates. According to this theory, a suitable loan modification scheme must be cognizant of both the borrower's ability and willingness to pay. The model indicates that effective modifications require writing down the principal balance.[2]

Concern that borrowers might behave strategically in response to lenders offering to modify loans might deter lenders' use of loan modification as a foreclosure alternative. Mayer, Morrison, Piskorski, and Gupta (2014) present evidence that borrowers may behave strategically in response to news of the availability of loan modifications for delinquent borrowers. This study analyzes borrowers' response to the program introduced by Countrywide Financial Corporation at the end of 2008 to settle a lawsuit filed by the U.S. state attorneys general, whereby interest rate modifications were offered to all subprime mortgages that were at least 60 days past due. The study finds a significant increase in borrower delinquency in response to the program, suggesting that borrowers were induced to become delinquent by the prospect of receiving a mortgage modification and payment reduction.

Portfolio versus securitized loans. The modification literature has also examined the potential differences between securitized and portfolio loans, with respect to modification decisions. Piskorski, Seru, and Vig (2010) emphasize three main reasons that securitized loans may be serviced differently from portfolio loans. First, servicer financial incentives may differ between the investor and portfolio contexts. Consistent with the framework of Jensen and Meckling (1976), investors force servicers to more fully internalize the costs and benefits of foreclosing or modifying

[1] The *ability to pay* is derived from having adequate cash flow or liquidity to make a monthly mortgage payment. *Incentive to pay* is a function of the borrower's equity stake in the home. Higher current loan-to-value (LTV) ratio would reduce incentive to pay, particularly when the value of the home is less than the loan balance.

[2] The model ignores any additional considerations on the servicer side and does not explain why principal write downs are relatively uncommon.

a loan. Second, private service agreements (PSAs) may legally bar servicers from using certain modifications. Third, property rights are jointly held by many bondholders, and coordinating an agreement among the bondholders on a particular modification scheme is more difficult than agreeing to a simple foreclosure. Similarly, Piskorski, Seru, and Vig (2010) and Agarwal, Ben-David, Chomsisengphet, and Evanoff (2011) find a higher incidence of loan modification for bank-held mortgages (portfolio loans) compared with similar securitized mortgages (investor loans).

Adelino, Gerardi, and Willen (2013), however, argue that the decision whether to modify a loan is based primarily on a servicer cost-benefit analysis, whereby the likelihood of success of a modification is assessed against the cost of proceeding through the foreclosure process. They argue, moreover, that the status of the mortgage as either bank-held or securitized has little bearing on this evaluation. They attribute the relatively sparsity of loan modifications before 2009 in part to a high probability of redefault and find evidence that servicers' increased reliance on loan modification as borrower self-cure rates declined between 2006 and 2010.

Potential selection bias. Haughwout, Okah, and Tracy (2009) caution, however, that "while we can tell that borrowers (and mortgages) that receive a modification are different from those that do not, we do not model how a mortgage gets into our modified sample." Servicers may choose whether or how to modify a loan based on private information about the borrower's creditworthiness at the time of modification, and the observed redefault rates among the modified loans may reflect these ex-ante characteristics. This possibility of selection effects precludes drawing strong inferences from the observed repayment performance of modified loans.

Redefault studies. Studies that examined the ex-post repayment performance of loan modifications granted during the initial stages of the mortgage crisis in 2007 and 2008 find troublingly high rates of redefault, calling into question the effectiveness of modifications. Haughwout, Okah, and Tracy (2009) analyze a sample of privately securitized, nonprime mortgages that were modified between December 2005 and March 2009 and find a "distressingly high" 56 percent average redefault rate within one year of modification. Similarly, Quercia, Ding, and Ratcliffe (2009) examine a sample of privately securitized, mostly nonprime mortgages originated in 2005 and 2006 that were modified in the second quarter of 2008. By the end of 2008, 45 percent of the modified loans had returned to delinquent status. Both studies find that redefault rates decline with the size of the payment reduction or principal reduction offered by a modification.

Subsequent studies, including from the U.S. Department of the Treasury (2012) and Schmeiser and Gross (2015) examining the performance of loans modified later during the crisis period (through at least 2011), confirm the significant relationships to the amount of payment or

principal reduction. Moreover, these studies demonstrate that principal reduction has a comparatively large impact on the likelihood of redefault because of the joint effects of payment reduction and the reduced loan-to-value ratio (LTV).[3]

Anderson, Kogler, and Kim (2012) conduct a multivariate analysis of 12-month redefault rates of privately securitized mortgages receiving modification in 2006 through March 2011. This study finds that the impacts of interest rate reduction and principal reduction on the likelihood of redefault are similar to those in the aforementioned studies. In addition, it finds a significantly higher probability of redefault for subprime loans and for loans receiving modification at a later stage of delinquency.

This study also finds a significant reduction in redefault rates of loan modifications after 2008. The study notes that this may reflect improving macroeconomic conditions or "improvement in the design and targeting of modifications that is not captured in payment reduction or modification type variables" but did not attempt to disentangle these effects. We fill in this gap in the literature by separating out macroeconomic effects both through the use of similarly situated self-cured loans as a control group and through the inclusion of macroeconomic factors directly in our estimated redefault equations.

Scharlemann and Shore (2015) apply a regression discontinuity approach to identify and mitigate the selection effect associated with modification type in evaluating the impact of the principal reduction on redefault. They examine modifications provided under the government-sponsored Home Affordable Modification Program (HAMP). HAMP's Principal Reduction Alternative (PRA) provides principal reductions for borrowers with negative equity, up to the point of meeting a negative equity target (usually 115 percent for the current LTV). On the margin, consistent with a PRA selection effect, the PRA principal reduction modifications have a more beneficial impact on redefault rate than is inferred from the extrapolation of the relationship of LTV to redefault in the HAMP population that is not eligible for PRA.

The most closely related study to ours is Goodman, Yang, Ashworth, and Landy (2013), which analyzes semiannual declines in the redefault rate on modifications of privately securitized

[3] Voicu, Weselcouch, and Tschirhart (2011), in addition to demonstrating that the likelihood of redefault is inversely related to both the amount of payment reduction and the amount of principal reduction, find that modifications associated with the U.S. Department of the Treasury's Home Affordable Modification Program (HAMP) were less likely to redefault compared with non-HAMP modifications. In addition, Schmeiser and Gross (2015) also find that term extension modifications that increase the amount of principal due are most likely to redefault.

mortgages over 2008 through 2012.[4] The authors discuss various factors that may have driven this downward trend, such as granting modifications earlier in the delinquency process and modifications with more generous payment relief.

Our contribution. Our paper provides a more extensive analysis of the improvement in the performance of loan modifications. We compare the performance of borrowers receiving a loan modification relative to a matched sample of self-cured borrowers, thus controlling for factors that might be important in determining the redefault rates of both groups (such as housing market recovery). We perform a separate payment performance analysis for privately securitized, agency securitized, bank-held conventional mortgages, and government-insured mortgages to account for potential differences in servicing practices across these investor and guarantor categories.

Our matching process, including the use of propensity scores, also ensures that the borrowers receiving modification and the matched self-cured are almost identical with respect to observable characteristics, thus narrowing the scope for selection effects. In other words, we make a best effort to mitigate potential selection effects associated with borrowers being selected to receive a loan modification, which clouds interpretation of the results in some previous studies.

Over the course of the downturn, we find an improvement in the performance of modified loans relative to self-cures. We find that increasingly generous modification terms played a role, along with improving economic conditions. Even after accounting for these factors, we still observe a larger decline in the redefault rate for modified loans, which may plausibly be attributed to servicer "learning-by-doing."

These findings are robust to restricting the sample to individuals in an advanced stage of mortgage delinquency. Thus, the improving performance of loan modifications that we observe is not owing to the moral hazard problem described by Mayer, Morrison, Piskorski, and Gupta (2014), whereby borrowers who have capacity to pay observe others benefiting from early modifications and intentionally miss some payments to qualify themselves for the modification program.

Despite our best effort, we may not be able to rule out entirely that the difference in redefault performance between modifications and self-cures may be tied to selection. However, even if it is tied to an evolving selection effect, improving performance of modifications relative to self-cure could lend itself to a learning-by-doing interpretation. Indeed, a key aspect of learning-by-doing could be to develop more appropriate criteria for selecting loans for modification.

[4] Richter, Nelson, and Seo (2010) cite an expanded offering of concessionary modifications that present significant payment reductions as the primary factor underlying a decline in redefault rates on modifications over the 2008–2010 period.

3. Institutional Background

At the onset of the crisis, most mortgage servicers were oriented toward foreclosing quickly on delinquent borrowers rather than engaging in loan modifications (Cordell, Dynan, Lehnert, Liang, and Mauskopf, 2009). A mortgage foreclosure, however, imposes significant costs on not only the homeowner and on investors and servicers but is also costly to local governments and may induce a drop in price of adjacent homes.[5] As the foreclosure inventory grew after the onset of the mortgage crisis, the rising costs spurred public and private efforts to expand loan modification activity in an effort to avoid foreclosure costs.

In 2008, the Federal Deposit Insurance Corporation (FDIC) published a Loan Modification Program Guide called "Mod in a Box" that provided a template for payment-reducing modifications for distressed mortgage borrowers. The guide emphasized an adjustment in the interest rate, an extension of the term of the loan, or the process of forgiving principal to reduce monthly payments to sustainable levels (characterized as a 31 to 38 percent ratio of debt payment to income). The guide was accompanied by a net present value (NPV) calculator that servicers could use to compare the NPV of the loan with and without the modification and thus facilitate the decision whether to offer a loan modification and with what terms.

Later in 2008, the Federal Housing Finance Agency (FHFA) introduced a formal program to modify delinquent government-sponsored enterprise (GSE) loans. The program was characterized by a set of borrower eligibility requirements and a recommended "waterfall" of maturity date, interest rate, and principal adjustments to achieve a target reduction in monthly payments. The program also featured an $800 incentive paid to the servicer for each implemented modification.

In 2009, this early effort was succeeded by the HAMP program, with the objective of further encouraging standardized modifications. HAMP mirrored the FHFA program with a waterfall modification protocol and servicer financial incentives, but it featured a larger budget and expanded pool of eligible loans (Cordell, Dynan, Lehnert, Liang, Mauskopf, and Kolb, 2011). At the onset of the program, 85 percent of all delinquent mortgages were eligible for HAMP modification (U.S. Department of the Treasury, 2009). In June 2010, HAMP was expanded further to encourage principal modifications under the Principal Reduction Alternative.

The development of these streamlined programs, along with the direct financial incentives offered to servicers, likely encouraged them to scale up their modification programs and facilitated the learning-by-doing process. In pursuit of efficiency, servicers had opportunities to learn-by-

[5] See, for example, Kingsley, Smith, and Price (2009).

doing; that is, servicers could improve the selection of loans for modifications and decrease the probability of further delinquency because modification practices became more refined from 2008 to 2011.

In addition to streamlining the modification process and offering financial incentives to servicers, government agencies also made data related to mortgage modifications and their repayment performance more readily available to the public. For example, the Office of the Comptroller of the Currency (OCC)'s quarterly *Mortgage Metrics Report* in mid-2008 vastly improved the public reporting of foreclosure and modification frequency and performance. The U.S. Treasury published the *Making Home Affordable Program Performance Report* to track the growth of HAMP modifications and their success after modification. The availability of these data may have facilitated learning-by-doing by lenders and servicers.

In 2013, the Consumer Financial Protection Bureau (CFPB) released new servicer guidelines that all large mortgage servicers must follow beginning in 2014 as Mortgage Servicing Rules under the Truth in Lending Act.[6] The publication of these servicing guidelines suggests that the learning-by-doing process has materialized in the form of uniform servicing standards that emphasize mortgage modification as an effective best-practice loss mitigation tool.

4. The Data

We explore redefault after modification or self-cure using a database that merges loan-level mortgage servicing data from McDash Analytics, LLC (a wholly owned subsidiary of Black Knight, Inc.) with borrower credit report data from the Federal Reserve Bank of New York/Equifax Consumer Credit Panel. This database is named Equifax Credit Risk Insight Servicing™ McDash (Equifax CRISM).[7]

The mortgage servicing component provides payment status (days past due), loan terms (interest rate and maturity date), and current balance for each mortgage, each updated monthly.[8]

---

[6] The Truth in Lending Act primarily features rules regarding how loss mitigation efforts should be handled and when foreclosure processes can begin after a loan becomes delinquent; specifically, it establishes longer timelines for nonforeclosure activities to occur.

[7] The algorithm used by Equifax CRISM to merge the two data sets, which is proprietary, uses information common to both component databases, including mortgage origination amount, mortgage origination date, zip code of the property (Black Knight McDash), zip code of the borrower (Equifax), current balance on the mortgage (at the end of each quarter), and the borrower's payment history.

[8] The Black Knight McDash data are collected from the 10 largest U.S. mortgage servicers and account for approximately 75 percent of all mortgages in the U.S. as of year-end 2010 (Black Knight McDash estimate). However, the data are provided without a servicer key that would allow for distinguishing between servicers.

For mortgages that enter into delinquency and subsequent foreclosure, the start and end dates of the foreclosure process are also reported. This information is used to identify mortgages that become seriously delinquent, those that receive a modification, and those that self-cure out of delinquency.

The mortgage servicing component of the Equifax CRISM data also indicate a loan's investor or guarantor category as one of the following: loans securitized and guaranteed by Fannie Mae and Freddie Mac (agency), loans insured by the Federal Housing Authority or Veterans Administration (FHA/VA), loans held in bank portfolios, and privately securitized loans. Our analysis distinguishes among these four categories.

In addition, these data provide the date of origination of the first mortgage, the original loan amount, the original appraised value of the property, the state and county location of the property, the borrower FICO® Score at origination, and the information on loan type (whether fixed rate, amortizing adjustable rate, or pay-option adjustable rate).

In addition to the mortgage servicing component, the Equifax CRISM data provide various updated information from the borrower's credit record. These include Equifax Risk Score (a credit score assigned by Equifax), information on any other first-lien mortgages the borrower may have (on properties other than the borrower's primary residence), and a variety of other indebtedness and payment history information, refreshed on a monthly basis. Finally, we combine the detailed loan and borrower information from Equifax CRISM with contemporaneous economic data, including the county-level repeat sales house price index (HPI) from CoreLogic and seasonally adjusted unemployment rates by county from the U.S. Bureau of Labor Statistics.

Sample definition. Our initial sample consists of first-lien mortgages for primary (owner-occupied) residences that became at least 90 days past due or subject to foreclosure in 2008, 2009, 2010, or 2011. From this overall population, we draw a 20 percent random sample. We then narrow the sample further to borrowers who went through a modification process or who self-cured from their mortgage delinquency during the period of 2008–2011, and who were no less than 90 days past due and no more than 540 days past due at the time of modification or cure.[9] This process yields a sample size of about 365,000 mortgages.

Next, we exclude all mortgages indicated (in the credit report data) to have an associated junior lien, which reduces the sample size to about 273,000. This exclusion is intended to simplify

[9] We apply a procedure to identify mortgage modification and/or self-cure that is adapted from Adelino, Gerardi, and Willen (2013) as described in what follows.

the analysis; as demonstrated in Calem and Sarama (2017), the dynamics of first- and second-lien default and cure are interrelated, which complicates modeling.

Finally, we exclude modified loans that were remodified and self-cured loans that subsequently were modified within 42 months after the initial modification or cure. This exclusion, which amounts to less than 1 percent of the sample, addresses a concern that remodification might have prevented redefault, causing the borrower's performance status to be ambiguous. The final sample contains 233,818 mortgages, 107,109 of which are unique self-cured loans and 126,709 are unique modified loans.[10]

For each mortgage loan included in the final sample, we track payment history through the second quarter of 2014 or until the loan terminates through redefault or payoff. As noted, our analysis compares the redefault behavior of borrowers who have received modifications with matched borrowers who have self-cured. The matching process further reduces the sample size owing to our inability to identify suitable matches for all modifications or all self-cures, as detailed in the next section.

Identifying mortgage modification. A loan is classified as undergoing modification if: 1) we observe changes made to the principal balance, interest rate, or maturity date yielding a material reduction in the monthly payment and 2) the mortgage returns from delinquent to nondelinquent (current) status.[11]

Principal reduction modifications are identified by comparing the current principal balance with both the origination balance and the previous month's balance. Similar to Adelino, Gerardi, and Willen (2013), we require that the current principal balance be at least 10 percent less than both the previous month's principal balance and the original balance but greater than 50 percent of the original balance. An exception is made for mortgages reported in Equifax CRISM that were assigned to a loss mitigation program, in which case, any reduction in principal is equated with a principal reduction modification.[12]

Interest rate modifications are identified by comparing the reported interest rate between the current and previous month. In the case of a fixed-rate mortgage, a loan modification is

[10] A few loans with missing information on loan balance, maturity date, or interest rate are excluded from our sample.

[11] Modifications (as identified by changes in loan terms) that do not return a loan to nondelinquent status appear to be relatively uncommon.

[12] As explained in Adelino, Gerardi, and Willen (2013), nonspecific loss mitigation flags included in servicing data are not comprehensive, necessitating the construction of modification indicators using reported changes in loan terms.

indicated by an interest rate reduction of at least 50 basis points. The same rule is applied to adjustable rate mortgages (ARMs), provided that the current month does not coincide with the original note's contractual reset date. When the current month does coincide with the reset date, if the ARM is reported in Equifax CRISM to have been assigned to a loss mitigation program, then a rate modification is indicated by an interest rate reduction of at least 1 percentage point. Otherwise, rate modification for an ARM is indicated by an interest rate reduction that is at least 1 percentage point and at least 50 basis points in excess of the decline in the index rate since the previous rate reset (or since origination, in the absence of a prior reset).[13]

One other type of modification, involving a combination rate and maturity adjustment, is identified by comparing the reported interest rate and the maturity date between the current and previous months. A modification is indicated if the maturity has been extended at least 12 months, the interest has been reduced by at least 12.5 basis points, and the required monthly payment has been reduced.

Each modified mortgage is uniquely assigned to a modification category, such that priority is given to principal reduction and term extension. Thus, if the loan is indicated to be a principal reduction modification, it would be assigned to that category regardless of whether an interest rate modification is also indicated. If rate and term modification but not principal reduction is indicated, the loan would be considered a rate and term modification.[14]

Identifying self-cure. A first mortgage is indicated to be self-cured if it returns to current status without the material reduction in the monthly payment indicative of a loan modification. Note that this definition does not rule out some assistance by mortgage servicers, such as granting a term extension that returns the borrower to current status but increases the monthly payment, or forgiving some accrued interest or penalties.

Sample composition. The bars with cross-hatches in Figure 1 show the composition of the prematch sample with respect to shares of modified versus self-cured mortgages, by year of cure or modification, within each investor or guarantor category. The dashed lines indicate total modified plus self-cured loan counts by year and category.

---

[13] The index rate, or market rate to which the mortgage note rate is tied, is represented by the three-month Treasury bill rate for this calculation.

[14] Starting in 2008, Black Knight McDash has provided detailed, servicer reported information on modifications for an unspecified subset of servicers, comprising roughly three-fourths of the loans included in the servicing data set. Since this is not a random subset of the servicing data, we do not use this data set for the analysis in the paper. However, it does provide a useful benchmark for cross-validation of our modification detection algorithm, against which our algorithm correctly classifies 97 percent loans transitioning from 90 or more days past due to current. This suggests that our algorithm accurately distinguishes self-cures and modifications while allowing us to use the full data set.

The total number of self-cured or modified loans increased markedly between 2008 and 2010, and especially within the agency and FHA/VA categories. The share of modified loans relative to this total also rose sharply between 2008 and 2011. Within the portfolio and privately securitized categories, the share of modifications doubled, while within the agency and FHA/VA categories, modification share increased more than five-fold from less than 10 percent to more than 55 percent.

The vast majority of payment-reducing modifications each year provided an interest rate reduction (occasionally combined with a term extension) but no forgiveness of principal. Table 1 reports, for the prematch sample, the share of loan modifications involving principle reduction by year. Notably, the share of principal write-down modifications increased steadily between 2008 and 2011.

Table 2 reports the prematch, sample mean values for various borrower and loan characteristics that are the basis for our matching procedure, by year of cure, cure type (modification or self-cure), and investor or guarantor category. As shown in Table 2, loans receiving modification tended to have larger outstanding balances and larger ex-ante interest rate spreads and tended to occur at later stages of delinquency. The share of modifications occurring at later stages of delinquency increased over time. Except within the FHA and VA category, refreshed LTV declined over time. Within all categories, average Equifax Risk Scores rose over time for both modifications and self-cures.

5. Matching Modified with Self-Cured Loans

We seek to compare the redefault behavior of borrowers who receive modifications versus similarly situated borrowers who self-cure. The latter serve as a control for factors impacting the sustainability of cure more generally. Both groups (modified and self-cured) go through a similar experience of initial delinquency, becoming current, and being at risk of redefault. What distinguishes them is that self-cures, unlike modified loans, did not receive financial relief via a payment reduction, which might have facilitated their remaining current. Some (not all) self-cures may have returned to current on their own without any restructuring of the payment schedule.

To ensure that the redefault rate comparison is between very similar borrowers (conditional on the available information), we apply a two-step matching process. First, we require that matched loans share the same product category, location of the property, delinquency status prior to cure, and year and quarter of cure. Next, within each defined segment, we match modified loans (treated) with self-cured loans (nontreated) using the propensity scoring process introduced

by Rosenbaum and Rubin (1983).[15] This matching procedure should significantly narrow (if not eliminate) the scope for selection effects in the observed redefault differential between modifications and self-cures.

Despite matching, we cannot entirely rule out that a selection effect may impact the evolving redefault performance of loan modifications relative to self-cures. Indeed, learning-by-doing is interpretable as a type of selection effect because it may be reflected in an evolving selection process for loan modifications. In other words, a key aspect of learning-by-doing is to develop more appropriate criteria for selecting loans for modification.

Propensity score model. The propensity scoring model relates a binary treatment indicator (modified versus self-cured) to observable characteristics of the borrowers or loans using a logistic regression specification. That is, we estimate the logistic regression model (1) to predict propensity $p(x_i)$ for borrower i of being selected for modification ($M_i = 1$):

$$p(x_i) = pr(M_i = 1 | X_i = x_i) = \frac{1}{1 + e^{-X_i\beta}} \quad (1)$$

where X_i is a vector of covariates, including both point-in-time and original characteristics of the borrowers or loans. We run three separate regressions based on equation (1) for three mortgage product types: FHA/VA loans, loans securitized and guaranteed by Fannie Mae or Freddie Mac (GSE), and loans held in bank portfolios or privately securitized, respectively.[16]

The explanatory variables included in the logistic regressions are dummy indicators for the location of the property (state fixed effects), year of origination, year and quarter of cure, and portfolio type (bank portfolio versus privately securitized portfolio).[17] Other explanatory variables include both point-in-time (updated) variables and the original characteristics of the borrower or loan (from the date of origination), as listed below.

---

[15] Propensity score matching is a process commonly used to account for observable heterogeneity across "treated" and "nontreated" entities, based on the conditional probability of treatment given observable characteristics, to reduce selection bias in treatment. In our study, the treated loans are modified loans and the nontreated loans are self-cured loans. For a more complete discussion of the origination and motivation for propensity score matching, see Guo, Barth, and Gibbons (2006).

[16] We group this way because servicers had broad discretion over modification decisions for private label securities, comparable with that which they exercised over their own portfolio. On the other hand, FHA/VA and GSE loan were subject to external guidelines of those agencies. Since there are relatively few portfolio loans, we pool them with privately securitized loans and include a portfolio indicator variable in the regression model.

[17] Since our data contain a single snapshot for each loan, the inclusion of origination year explains most of the variation related to loan age as of the cure date. Thus, we exclude it from the propensity scoring models. Estimated coefficients and model fit are nearly identical when the loan age is included.

Point-in-time variables include a change in the local house price index over the year prior to cure, interest rate spread between the mortgage interest rate and 10-year Treasury rate, indicator variables that capture the ranges of delinquency status (days past due) as of the month prior to cure, and indicator variables for ranges of refreshed LTV ratio.[18] Other point-in-time variables are the log of the mortgage principal balance, the Equifax Risk Score, bankruptcy status, and an indicator for multiple first mortgages. Unless otherwise noted, each of these variables is measured as of three months prior to the date of cure.

Original characteristics include an indicator for being a subprime borrower (defined as having FICO® Score at origination no greater than 620 and for jumbo mortgage) and an indicator for retail origination channel.[19] Also included are indicators distinguishing ARM categories from fixed-rate mortgages.[20]

Propensity score model results. The logistic regression results based on equation (1) are presented in Table 3. The estimation results indicate that a bankruptcy filing is negatively associated with the likelihood of modification relative to self-cure. Loans with refreshed LTV below 90 percent have reduced probability of modification relative to self-cure. The coefficients of the delinquency segments indicate that a cure is more likely to be associated with a loan modification as borrowers fall more behind in their mortgage payments.

Loans with larger interest rate spreads and loans with larger balances are more likely to cure through modification. For borrowers with multiple first mortgages, their primary residence is less likely to cure through modification. With the exception of FHA and VA loans, the likelihood of modification relative to self-cure increases with Equifax Risk Score and decreases with more favorable housing market conditions.

Matching modifications to self-cures. The first step in matching modified loans to similarly situated self-cured loans is to divide all cured loans into broad segments based on geographic

[18] The refreshed LTV is calculated as the principal balance of the mortgage divided by the current property value. The latter is based on the original appraised value updated using the county-level house price index from CoreLogic. The specified ranges of refreshed LTV are > 80 and ≤ 90; greater than 90 and ≤ 100, and > 100 percent. The specified delinquency status categories are ≥ 120 and < 180, ≥ 180 and < 270, ≥ 270 and < 360, and ≥ 360 days past due.

[19] The Equifax CRISM data include a jumbo mortgage identifier and a servicer-provided classification of the mortgage as subprime at origination that we use to identify subprime mortgages if the FICO® Score at origination is missing.

[20] The ARM categories distinguished are pay-option loans allowing negative amortization (option ARM), mortgages that allow monthly rate adjustment (variable ARM), mortgages with one-year initial fixed-rate periods, those with two- or three-year initial fixed-rate periods, and those with initial fixed-rate period longer than three years (other ARM).

location (the state in which the property is located), date of modification or cure, delinquency bucket (same delinquency status in the month prior to being cured), and investor or guarantor category. Each of these segments contains both modified and self-cured loans. In the next step, we match modified loans to self-cured loans within the same segment based on the estimated propensity score, which is the predicted value for probability of modification from equation (1). We use the method of near-neighbor, caliper matching to identify modified and self-cured loans with sufficiently close propensity scores.[21]

We allow multiple self-cured loans to be matched to a unique modified loan in the same segment. We assign a weight of 1 to each modified loan. Each of the matched self-cured loans matched to a given modified loan is weighted by the reciprocal of their total count so they are weighted equally and their weights sum to 1.

In the event of no matches being found for a modified loan within the caliper, the observation is dropped from the analysis. To minimize the loss of observations of modified loans because of a lack of suitable matches, we allow for the replacement in the matching process such that a particular self-cured loan may be paired with multiple modified loans in the same segment, up to a limit of 25 uses of the same self-cured loan.[22] If a self-cured loan is used as a match for more than one modified loan, then its sample weight is calculated as the sum of its weights across all modified loans with which it is paired.

The match rate between modified and self-cured loans is affected by our choice of caliper interval. A larger caliper interval would increase the matching rate but would be more likely to result in less accurate matching. Following Ding, Quercia, Li, and Ratcliffe (2011), we select a caliper of 0.1 for our analysis.

Table 4 quantifies the outcomes of the matching process, by year of modification or self-cure, and by investor or guarantor category. Panel A reports the percentage of modified loans successfully matched to at least one self-cured loan, panel B reports the percentage of self-cured loans used for at least one matched modification, and panel C provides some information on the frequency of multiple matches per modified loan.

---

[21] This method involves selecting pairs of modified and self-cured loans within the same characteristic segment, with absolute difference in propensity scores less than a specified caliper value (α). Alternative matching algorithms found in the literature include one-to-one matching, kernel matching, local linear matching, and Mahalanobis metric matching (Guo, Barth, and Gibbons, 2006).

[22] In cases in which this limit would be exceeded (a particular self-cured matches to more than 25 loan modifications), we prioritize use in one-to-one matches such that no other matching self-cures are available for the particular loan modification. Beyond that, we prioritize use among fewer total matches for a particular loan modification, and beyond that, the selection is random.

Excluding loans held in bank portfolios, the majority of modified loans are successfully matched to at least one self-cure, with success rates ranging from 55 percent to 78 percent, depending on the year and investor or guarantor grouping. For loans held in bank portfolios, the match success frequency ranges between 43 percent and 54 percent, reflecting the smaller number of loans in this category. The majority of self-cured loans are not employed as a match because their propensity scores are not sufficiently close to those of modified loans in the same segment.

The solid bars in Figure 1 show composition of the postmatch sample with respect to the weighted share of modified loans, by year of self-cure or modification and by investor or guarantor category. The solid lines indicate the total loan counts by year. Since unmatched loans have been dropped from the sample and there are proportionately more self-cures left unused as matches than modified loans left unmatched, total (postmatch) loan counts are smaller and the share of modifications is somewhat larger compared with the prematch composition.

Table 5 reports the postmatch, weighted sample mean values for the same set of variables reported in Table 2, again by year of cure, cure type, and investor or guarantor category. Because of matching, both self-cures and modifications have similar mean values postmatch; the primary exception is that modifications continue to exhibit somewhat larger average loan balances than self-cures within the agency grouping.

Identifying redefault. The matched sample allows for controlled comparisons of redefault rates between modified and self-cured loans. However, defining redefault is not as straightforward as one might initially surmise. Many borrowers return to delinquency after being modified or self-cured. However, such lapses often are only temporary (the borrowers quickly cure again). Some borrowers redefault, cure, and fall behind again, ultimately being unable to cure.

We settled upon the following definition of *redefault* as reasonably indicative of a long-term return to delinquency. First, we define a *redefault event at date* t as: 1) the self-cured or modified loan returns to severe delinquency (90 or more days past due, in foreclosure, in real estate owned (REO), or involuntarily liquidated) at date *t* and 2) delinquent status is confirmed (the loan is observed to be at least 30 days past due, in foreclosure, in REO, or involuntarily liquidated) as of six months after date *t* or as of its last observed performance date, whichever comes first.

We restrict attention to redefault events that occur within 36 months after modification or self-cure and define redefault as the occurrence of at least one redefault event within this 36-month period. For loans with more than one redefault event within the 36-month period, we use the date of the first redefault as the redefault month.

Remodification. On occasion, within the 36-month window, a modified or self-cured loan returns to delinquency and, before six months has passed, is granted a modification that resets it to current, precluding a redefault event. If these loans otherwise are not observed to redefault during the 36-month window, we exclude them from the sample; their redefault status becomes ambiguous because of the remodification. This exclusion only has a small impact — less than 1 percent of the loans in the sample are affected.[23]

Comparative redefault rates. In Figure 2, we compare the monthly cumulative redefault rates of modified loans with the monthly, weighted cumulative redefault rates of their matched self-cures, by investor or guarantor category, separately for the earliest (2008) and latest (2011) year-of-cure cohorts in our sample. We plot these cumulative redefault rates over a 36-month window after the loans had returned to nondelinquent status. For ease of visualization, we also show cubic polynomial approximations to the monthly data points.

The portfolio, agency, and private securitized categories exhibit similar patterns, characterized as follows. Redefault rates are much lower for the 2011 cohort compared with the 2008 cohort, for both modified loans and their matched, weighted self-cures. However, the decline in redefault frequency is markedly larger for loan modifications than for self-cures. In 2008, loan modifications have a higher frequency of redefault than self-cured loans, but by 2011, the ordering is reversed.

For example, among agency loans, the 36-month cumulative redefault rate for the 2008 cohort was around 80 percent for modifications and 70 percent for self-cures. The 36-month cumulative default rate for the 2011 cohort was about 20 percent for modifications and 35 percent for self-cured loans.

Improvement in performance between 2008 and 2011 is much more modest for the FHA/VA category; however, the decline in redefault rates is larger for modifications than for self-cures. Given the relatively small changes in performance for this category, we focus primarily on agency, portfolio, and private securitized loans for the remainder of the paper.

Figure 3 presents pairwise comparisons for successive year-of-cure cohorts. For the sake of brevity, we restrict attention to the agency mortgage category; very similar patterns are exhibited in the privately securitized and portfolio categories. Again, the charts depict monthly cumulative

[23] Similar to other studies of redefault (e.g., Adelino, Gerardi, and Willen, 2013), we do not consider prepayment in our analysis because the likelihood of loans prepaying after modification or self-cure is small. Only 11 percent of loans in our sample prepay within three years of their modification or self-cure date. The redefault rate within three years of modification or self-cure is more than four times as large (47 percent).

redefault rates of modifications and matched, weighted self-cures through a 36-month window after the initial cure, along with cubic polynomial approximations to the monthly data points.

Within each investor or guarantor category, most of the improvement in performance is seen for the 2009 cohort compared with 2008 and for 2010 versus 2009. The decline in redefault rates between 2008 and 2009 is substantially larger for modifications compared with self-cures. From 2009 to 2010, the decline in redefault rates is about the same for loan modifications as for self-cures. From 2010 to 2011, the improvement in performance is more modest and larger for modified loans compared with self-cured loans.

Alternative sample constructions and default definitions. Qualitatively similar redefault rate trends are observed if we reverse the matching and weighting procedure, whereby each self-cured loan is assigned a weight of 1 and potentially matched to multiple modified loans (allowing the reuse of modified loans in different pairings).[24] We again find that the redefault rates decline over time for both modified and self-cured loans, such that the decline in redefault rates is larger for modifications. We prefer to use one-to-many matching because it ensures that all modified loans, which are the subject of our study, are given equal influence over the final results.

For robustness testing, we also examined redefault rate patterns using an alternative definition of redefault, such that we specify redefault as any reoccurrence of severe delinquency within 36 months of modifications or self-cures, whether or not the reoccurrence is transient. Not surprisingly, redefault rates are generally higher under this definition, and they do not decline as much over time. More important, redefault rate trends are similar to those observed using our original, preferred definition of redefault. The decline in redefault rates over time remains substantial and remains larger for modifications compared with self-cures under the broadened definition. Thus, the results are qualitatively robust to a broader definition of redefault.[25]

Explanations for improving redefault rates. Improving macroeconomic and housing market conditions was probably one of the key factors in driving the improving performance of both self-cured and modified loans between 2008 and 2011. In other words, the stabilization followed by recovery in the economic and housing market conditions beginning in 2010 contributed to the declining redefault frequencies of both self-cured and modified loans.

---

[24] Likewise, similar results are obtained if we forego matching entirely and use the uncontrolled (prematch) population. The differences between modifications and self-cures are somewhat more pronounced for the uncontrolled population.

[25] Moreover, the larger decline in redefault rates observed for modifications cannot be attributed to differential rates of prepayment between modifications and self-cures. Modified loans in our sample exhibit slower prepayment speeds than self-cured loans, and modifications' prepayment rates increased by less over time than self-cures' prepayment rates.

Another possible factor driving improved performance of both self-cured and modified loans is that borrowers who became delinquent in the later stages of the mortgage crisis period tended to be less vulnerable to repeat shocks compared with their predecessors. Hence, they were better able to sustain a self-cure or modification.

Alternatively, over time, servicers may have become more effective at helping borrowers stay current following a self-cure or modification, such as through counseling and early intervention. In other words, mortgage servicer learning-by-doing may have contributed to improving the repayment performance of both self-cured and modified mortgages.

We can potentially draw from our data insights regarding why the decline in redefault rates was greater for loan modification compared with self-cure. We explore this issue in the next section.

6. Logistic Regression Models of Redefault

Building on our visual analysis of redefault patterns over time, we further explore the decline in redefault rates of modified loans in relation to self-cures. We exclude government-insured (FHA and VA) loans from this additional analysis since we have observed different behavior for this category, with relatively little change in redefault rates between 2008 and 2011.

Modification advantage. Our point of departure is the hypothesis that modification bestows an advantage by making a cure more sustainable. That is, conditional on observable characteristics of the borrower and loan, a borrower who cures via loan modification is advantaged relative to one that self-cures because of the financial relief provided by the modification. However, aside from this financial advantage and conditional on observable characteristics, there is little reason to expect modified and self-cured loans to have differing likelihoods of redefault.

We further posit that the extent to which modification bestows an advantage depends on the generosity of the adjusted repayment terms and potentially on the following, additional factors: 1) the economic environment, 2) the length of delinquency (number of days past due) at the time of modification, and 3) modification vintage (calendar year and quarter). Intuitively, the modification is expected to be more likely to succeed when combined with improving economic conditions. A borrower in longer-term delinquency when the modification is granted is expected to be in a more precarious financial condition, making the modification less effective. Modification vintage captures any improvement in the effectiveness of loan modifications over time, such as from learning-by-doing.

To test these hypotheses, we proceed as follows. First, we estimate a logistic regression model that predicts redefault probability for self-cures in the postmatch sample. Second, we apply the estimated coefficients from that model to the sample of postmatch modified loans to calculate each loan's implied probability of redefault (its redefault "score"). That is, we predict each modified loan's likelihood of redefault conditional on there being no systematic difference between similarly situated borrowers based on whether they self-cured or received a modification. Third, we estimate a logistic regression model that predicts redefault probability for loan modifications in the postmatch sample. The explanatory variables here include the loan's calculated likelihood of redefault (from Step two) along with other factors that may impart an advantage to a borrower with a loan modification, as discussed previously. Finally, we focus on whether these other factors are significant. We expect that some of these other factors would be (negatively) significant, lowering the redefault probability of modified loans relative to self-cures.

Redefault model for self-cures. We first estimate the logistic regression model shown in equation (2) that predicts redefault probability for self-cures:

$$redefault\ flag_i = \alpha + \beta_0 selfcure_{2009Q2_i} + \cdots \beta_4 selfcure_{2011_i} + \gamma \cdot Z_{it} + \eta \cdot X_i \quad (2)$$

The dependent variable $redefault\ flag_i$ is a binary indicator that is equal to 1 if the self-cured loan *i* redefaults and equal to zero otherwise. We use the postmatch sample of self-cured loans (based on one-to-many matching of modifications to self-cures), weighting each observation as described earlier.

The "vintage" dummy variables $selfcure_{t_i}$ indicate the specific year and quarter when the self-cured loan *i* returned to current, leaving the peak of the crisis period (all quarters in 2008 and 2009:Q1) as the baseline period. The vector Z_{it} represents a set of independent variables that measure local economic conditions that could impact the repayment performance of loan *i* subsequent to the modification period *t*. Specifically, we include in Z_{it} change in the county unemployment rate and percentage change in the county house price index during the 18 months following the cure date, each splined at 0.[26]

The vector X_i represents a set of independent variables that measure the risk characteristics of the loan *i* and the associated borrower. These include the Equifax Risk Score and most of the other explanatory variables that were used to predict the likelihood of receiving a

[26] We limit local economic shocks to 18 months because roughly three-fourths of redefaults happen during this period and because inclusion of additional variables measuring economic conditions over the remainder of the observation period (from 18 to 36 months) was found to have no important impact on the estimation results.

modification in the propensity score equations because they are potentially related to the likelihood of redefault as well.[27]

Applying the estimated model (2) to "score" modified loans. We now apply the estimated coefficients from the self-cure redefault model in equation (2) to the sample of postmatch modified loans as shown in equation (3):

$$score_i = \alpha + \beta_0 mod_{(2009Q2-Q4)_i} + \cdots \beta_4 mod_{2011_i} + \gamma \cdot Z_{it} + \eta X_i \quad (3)$$

The right-hand side of equation (3) is the imputed redefault probability of the modified loan based on the estimated redefault equation (2) for self-cures. Our use of one set of equations to create a predictive variable for another set is analogous to the use of a credit score for predicting delinquency. Similar to credit scores, we estimate a probability-of-default equation based on loan and consumer characteristics, using a "development sample" (the self-cured loans). We then apply this equation to score the likelihood of default of the individual loans in a population of interest (the matched modified loans).

Redefault model for loan modifications. Next, we estimate the logistic regression model shown in equation (4) that predicts redefault probability for modified loans:

$$redefault\ flag_i = \mu + \delta_0 \cdot score_i + \theta \cdot Y_i + \lambda \cdot Z_{it} + \varphi_0 mod_{(2009Q2-Q4)_i} + \cdots + \varphi_4 mod_{2011_i} \quad (4)$$

The term $score_i$ in equation (4) is the imputed redefault probability of the modified loan based on equation (3). In response to the estimated regressor problem associated with using this fitted value ($score_i$) as an independent variable in the loan modification redefault equation, we employ bootstrapped standard errors for the latter equation's estimated coefficients.

The estimated coefficient δ_0 of $score_i$ provides a test of whether, as hypothesized previously, the determinants of redefault for modified and self-cured loans are largely the same after accounting for the financial relief provided by a modification. That is, δ_0 is expected to be close to 1 if, aside from the financial advantage associated with a modification, the same factors are important in determining redefault probability for both modified and self-cures.

The terms Z_{it} and Y_i in equation (4) represent factors potentially associated with differing redefault probability of modified relative to self-cured loans. By including these additional terms, we test the factors posited previously as potentially affecting the degree to which modifications bestow an advantage.

[27] We reduce the number of delinquency categories to two: 180–269 days past due and more than 270 days past due. A few categorical variables are excluded from the final specification of the redefault equation for self-cured loans because specification testing had indicated that they were neither statistically significant nor had any material impact on estimation results.

We include in Y_i an indicator for principal forgiveness modification, and a piecewise-linear spline term measuring percentage reduction in the mortgage payment due to the modification (with a single knot point at 15 percent). These variables capture the financial benefit accruing to the borrower as a consequence of the modification. In addition, we include indicators for delinquency (days past due) segment as of the month prior to modification. In Z_{it} we reinclude the local economic variables from equation (2), which are implicit in $score_i$. These account for the possibility that the repayment advantage bestowed by a modification is most effective when combined with improving economic conditions.[28]

Finally, we include in equation (4) a set of "vintage" dummy variables $mod_{(2009Q2-Q4)_i}$, mod_{2010_i}, and mod_{2011_i} indicating that loan *i* was modified in 2009:Q2 through 2009:Q4; 2010, or 2011, respectively. We expect the coefficients of the vintage indicators to be negative and significant if, relative to the base period (2008:Q1 through 2009:Q1), there had been significant improvement in the effectiveness of loan modifications, such as from learning-by-doing.

We estimate a pair of equations for agency and nonagency (portfolio and private securitized) mortgages, respectively. In the nonagency equation, we add a dummy variable to distinguish portfolios from privately securitized loans.

Empirical results: self-cures. Table 7 presents the estimated redefault model for the postmatch self-cured samples based on equation (2). The results are as expected. The sustainability of self-cure is related to the local house price and unemployment trends; that is, rising unemployment increases the likelihood of redefault, while rising house prices mitigate it. Moreover, borrowers who have lower refreshed LTV prior to self-curing are more likely to sustain the cure (less likely to redefault). In addition, self-cured borrowers with higher Equifax Risk Scores are less likely to redefault, while subprime mortgages and borrowers who have multiple homes are more likely to redefault. For agency loans, borrowers who are more than 180 days delinquent at the time of cure are also more likely to redefault.

The results also show that while the economic variables and risk measures exhibit the expected associations to redefault risk, they do not explain the entire improvement in self-cure redefault rates between 2008 and 2011. Much of the improving performance of self-cures is captured by the vintage dummy variables. The vintage indicators may capture more general

[28] Note that the imputed probability or score already incorporates a comprehensive set of predictive factors and that separately including these factors alongside the score variable in equation (3) poses the potential for degrading collinearity. We do not separately control for factors other than those in Z_{it} or Y_i as we deliberately employ a parsimonious specification, restricting attention to variables that are related to the advantages provided by a modification.

improvement in macroeconomic and housing market conditions or increasing resiliency of the self-cure population tied to unobservable factors (those not captured in the independent variables in X_i and Z_{it}). In addition, the vintage indicators may capture mortgage servicers learning-by-doing for their ability to sustain self-cured borrowers' performance.

Empirical results: modified loans. Table 6, panels A and B, report the postmatch sample, weighted mean values of the principal forgiveness indicator variable and the payment reduction from loan modification, by year of modification, within each investor or guarantor category. Both the share of principal forgiveness modifications and the size of payment reductions increased over time, which we expect would be reflected in improving repayment performance of modified loans.

Table 8 presents the coefficients estimated based on equation (4). Columns 1 and 3 present the regression results for agency loans and private securitized (or portfolio) loans, respectively. Columns 2 and 4 present similar analysis for agency loans and private securitized (or portfolio) loans, respectively, but restricting the sample to modified loans that were at least 120 days past due at modification, which is described in greater detail under the robustness testing section.

For each loan category, the estimated coefficient on the imputed redefault probability is close to 1; specifically, 1.14 for agency loans (column 1) and 0.99 for portfolio loans (column 3). Thus, the redefault behavior of modified loans closely resembles that of similarly situated self-cured loans after the inclusion of the additional terms to account for the financial relief provided by a modification, consistent with the modification advantage hypothesis discussed previously.

Impact of modification terms. The likelihood of the redefault of a modified loan exhibits statistically significant, inverse relationships to the principal modification indicator and to the size of the payment reduction. Thus, increasingly generous payment terms on modifications and improving economic conditions over the course of the study period contributed to the larger decline in the redefault rate of modified loans compared with self-cured loans. These findings confirm our previous hypothesis regarding other important factors determining the unique advantage of modifications.[29]

Modification vintage effects. Even after accounting for the generosity of the modification terms and the improving economic conditions, much of the improvement in the payment performance of modified loans (relative self-cures) is captured by the modification vintage terms. The results indicate a large decline in the redefault rate of modifications after the first quarter of

[29] We also find that loan modifications at later stages of delinquency, for both for agency and private securitized (or portfolio) loans, have higher probability of redefault.

2009 and an additional, modest decline after 2010, consistent with the matched-pair visual comparisons in Figure 3.

Odds ratios associated with the estimated coefficients of the modification vintage terms from model (1) are shown in Table 9. The odds of redefault in the second through fourth quarters of 2009, relative to the 2008 and early 2009 baseline, are 0.73 for agency loans and 0.65 for privately securitized and portfolio loans, respectively. These odds rise slightly in 2010 to 0.77 and 0.69, respectively, and then drop to 0.63 and 0.56, respectively, in 2011.

Robustness checks. These results are robust to controlling for other factors that may be associated with differences in the performance of modified versus self-cured loans. We tested inclusion (in Y_i) of the Equifax Risk Score, refreshed LTV, the subprime indicator, loan age at cure, the indicator for retail origination channel, and the indicator for jumbo mortgages. In each case, we found no important impact on the other estimated coefficients or on the model's goodness-of-fit.

In addition, we reestimated the equations in Table 8 by dropping the loans associated with consumers who have multiple first-lien mortgages. Moreover, we checked robustness to excluding all but the nearest neighbor from the original one-to-many match (nearest-neighbor matching) and to reweighting based on the alternative, many-to-one matching process described in Section 5. In each case, the results did not change in any substantial way.

We also reestimated the redefault equations separately for adjustable- and fixed-rate mortgages (ARM and FRM) in the combined, portfolio and private securities category and tested inclusion of product type indicators in the redefault equations for GSE loans (which are predominantly FRM). Results from the estimated redefault equations for FRM in the combined, portfolio and private securities category were qualitatively similar to those reported for the full (ARM and FRM) sample. Inclusion of the product-type indicators had no material impact on the estimated coefficients of other variables in the redefault equations for GSE loans.

Interestingly, the estimated regression equations for ARM in the combined, portfolio, and private securities category yielded somewhat divergent results, not indicating a larger decline over time in the redefault probability for modifications relative to self-cured loans.[30] This close similarity may be explained by the fact that 78 percent of the self-cured ARMs in this category arrived at their initial rate reset date before the self-cure date, and another 12 percent did so within one year after the self-cure date. Since market interest rates were declining during this period, self-cured loans

[30] We do, however, continue to observe a mitigating impact of principal forgiveness modification on the likelihood of redefault.

that hit their initial rate reset experienced substantial payment reductions, which acted as a natural modification and made them largely indistinguishable from rate-reset modifications.

Testing for a potential role of "strategic default." The modification vintage terms capture improvement in the performance of loan modifications (relative to similarly situated self-cures) that is tied to factors we cannot specifically identify. One such conceivable factor could be an increasing frequency of borrowers opting to become delinquent on their mortgages to become eligible for a loan modification, such as in Mayer, Morrison, Piskorski, and Gupta (2014) and Jagtiani and Lang (2011). If the frequency of borrowers engaging in such strategic behavior increased as modification activity expanded, then that could explain declining redefault rates on modifications, as such borrowers would have little incentive to redefault after receiving their sought-after modification.

We believe the likelihood of such strategic behavior is small overall and is greatest when borrowers perceive modifications to be quickly obtainable.[31] That is, the likelihood of strategic default declines the longer the wait for a modification loan because of the greater harm to the borrower's credit score, accumulating late fees, and increasing risk of foreclosure. Thus, one way to mitigate any impact of strategic default is to restrict the sample to borrowers who became at least 120 days past due before receiving their loan modification.

The results from reestimating the baseline specification (equation 3) using the restricted sample of modified loans (which were deep in delinquency status prior to receiving modification) are presented in Table 8, column 2 (agency loans) and column 4 (portfolio loans). The results are not materially different from the full sample results of Table 8, columns 1 and 3, suggesting that a strategic default was not an important factor in driving the improvement in redefault performance after 2008.

Testing the impact of HAMP (using a full set of quarterly dummies). The observed vintage effects could at least in part reflect the introduction of the HAMP modification program. To explore this possibility, we tested the inclusion of a full set of post-2008 quarterly dummy variables for the date of modification or self-cure (in place of the grouping in our main specification). The results indicate a significant decline in the redefault rate (relative to the 2008 base year) in 2009:Q2, which is about the same time as the announcement of the HAMP modification program on March 4, 2009. While this is not conclusive proof that HAMP was influential, the timing does closely correspond.

[31] The specific Countrywide Mortgage program studied by Mayer, Morrison, Piskorski, and Gupta (2014) likely encouraged strategic default because it became widely publicized that borrowers were eligible for modification as early as 60 days or more past due.

Additional, substantial declines in the redefault rate of modified loans (relative to self-cured loans) occurred after 2009:Q2, although there were no additional modification program announcements.

Summary. Our analysis has highlighted key factors contributing to the larger decline in the redefault frequency of modified loans compared with self-cured loans between 2008 and 2011. First, consistent with Goodman et al. (2012), we find evidence indicating that the improvement in the performance of loan modifications (relative to self-cures) can be attributed to an increased share of principal modifications, which on average perform better than other types of modifications. Second, the improving relative performance of a loan modification is also attributable to larger payment reductions associated with modifications in vintages after 2008. Third, the favorable impacts of principal modification and the larger payment reductions were enhanced by improving economic conditions, with modifications becoming more effective as unemployment rates declined and home prices rose.

The analysis confirms and expands on previous findings in the literature. In particular, Goodman, Ashworth, Landy, and Yang (2012) and Goodman, Yang, Ashworth, and Landy (2013) argue that the decline in the redefault rate after 2008 reflects modifications occurring at earlier stages of delinquency in the later vintages. Our analysis confirms that earlier intervention is associated with the reduced redefault probability of modified loans relative to that of similar self-cured loans. However, our analysis also indicates that the time in delinquency before modification was actually lengthening after 2008. The improvement in the payment performance of the modifications after 2008 was associated with later (rather than earlier) intervention. Therefore, we cannot attribute the improving performance of modifications relative to self-cures to earlier interventions.[32]

Learning-by-doing is our preferred explanation for the significant vintage effect during the last three quarters of 2009 (relative to 2008 through first quarter of 2009 baseline); it is intuitively plausible that loan modifications became more successful because servicers performed a large number of mortgage modifications and observed and learned from the outcomes. Early in the crisis, many servicers had limited experience designing modification programs. As modification activity

[32] Goodman et al. (2011) suggest that declining redefault rates on loan modifications during 2008–2011 may reflect an increasing number of loans experiencing a remodification. Since we exclude remodifications from our sample ex ante, this explanation is not applicable here. However, the frequency of remodification was very low (as noted earlier, less than 1 percent of loans were excluded because of a modification subsequent to the initial modification or cure). Therefore, incidence of remodification is unlikely to have had a significant impact on the redefault rates of modified loans.

ramped up, particularly during 2008 and into early 2009, servicers may have learned how to design and implement the programs more successfully.

Learning-by-doing in regard to loan modification might be manifested in servicers becoming more adept at screening borrowers for eligibility. Based on the repayment performance associated with previous modification decisions, servicers could be revising their models, criteria, and NPV calculations in their assessment of whether a modification is preferable to inaction or foreclosure to achieve the best outcomes. In addition, mortgage servicers could have learned to tailor the most effective modification terms to specific individual borrower circumstances and to expand or enhance their default prevention tools and activities such as postmodification financial counseling.[33]

We note that the observed vintage effects may also reflect changes in the population characteristics of borrowers receiving modification. For example, as indicated in Table 5, compared with later years, 2008 defaulters in the agency category had relatively high, refreshed LTV, and especially in the privately securitized (or portfolio) category, they were more likely to have subprime characteristics. However, our estimated vintage relationships are robust to controlling for these factors, and the 2008 defaulters otherwise were not observably much different from later defaulters. Thus, learning-by-doing is a robust explanation.[34]

7. Concluding Remarks

The foreclosure crisis from 2007 to 2012 brought about renewed interest in loan modification programs to assist in the recovery from default. However, there remains much to learn about the cost-effectiveness of mortgage modifications. Early in the mortgage crisis that developed during 2007 and 2008, the redefault rates of modified loans were quite high, validating the common perception that loan modifications are not cost-effective. However, over the course of the downturn and in the early recovery periods, loan modifications increasingly achieved their goals.

[33] One caveat is that the observed vintage effects may also be associated with larger shares of modification being granted (in later vintages) to loans that could have self-cured without any intervention. That is, modification may appear increasingly successful because the servicer is more frequently providing payment or principal reductions to borrowers who would have self-cured. However, only the learning-by-doing explanation is consistent with servicers seeking to improve the efficiency of their modification programs and minimize their losses associated with defaulted mortgages.

[34] We are somewhat more agnostic to the further improvement in performance indicated by the estimated 2011 vintage effect. On the one hand, as the economy and housing prices had begun to stabilize by 2011, these later defaulters, who had survived the worst of the downturn, may have been systematically different along unobservable dimensions than earlier cohorts. On the other hand, additional learning-by-doing might have occurred as the economic context evolved.

Our study examines the decline in the redefault rates of loans that were selected for modification during 2008–2011, using similarly situated, self-curing borrowers as a control group. We find that while the performance of modified and self-cured loans both improved dramatically after 2008, the improvement of modified loans was substantially greater than that of similarly situated self-cures.

We identify key factors that potentially contributed to the larger decline in the redefault frequency of modified loans compared with similarly situated self-cured loans. One factor was an increasing share of principal modifications, which on average perform better than other types of modifications. In addition, the analysis indicates that more generous modification terms (larger payment reductions) over time was a key contributing factor. Moreover, the favorable impacts of principal and payment reductions were enhanced by improving economic conditions, resulting in more effective modifications.

Interestingly, even after accounting for all these factors in the model, much of the observed differential improvement in performance of modified loans (relative to similarly situated self-cures) is captured by modification vintage terms. We observe a particularly large drop in the redefault rate of modified loans relative to self-cures after the first quarter of 2009.

One plausible explanation for this residual effect is servicer learning-by-doing. That is, as servicers gained experience via expanded loan modification activity in the early stages of the mortgage crisis, they refined the criteria used to select loans for modification, designed the most effective modification terms for specific circumstances, and became proactive in providing post-modification counseling. We believe that such a learning-by-doing process, wherein servicers learned from past mistakes and successes, likely contributed to declining redefault rates. Information dissemination by government agencies may have also helped to facilitate this learning-by-doing process.

Our learning-by-doing evidence suggests that additional research would be beneficial for future modification policy and practice. Future research could further investigate the learning-by-doing hypothesis, such as by identifying and documenting specific improvements to loan modification strategies and practices. Future research could incorporate additional data to more fully distinguish learning-by-doing from changes in the population characteristics of borrowers receiving modification. Another useful topic for future research is optimal policy intervention: whether servicers should receive subsidies for mortgage loan modification, to whom subsidies should be targeted, and what strategies might further enhance the effectiveness of modifications.

Overall, our findings are supportive of the public policy that encouraged loan modification activity because, over time, modifications proved far more successful than a priori experience would have suggested. Further research incorporating a full cost and benefit quantification would be necessary in determining the net benefit of mortgage modifications from the lender, borrower, and social welfare perspectives.

References

Adelino, M., Gerardi, K., and Willen, P. (2013). "Why Don't Lenders Renegotiate More Home Mortgages? Redefaults, Self-Cures and Securitization." *Journal of Monetary Economics*, 60(7), pp. 835–853.

Agarwal, S., Amromin, G., Ben-David, I., Chomsisengphet, S., and Evanoff, D. (2011). "Market-Based Loss Mitigation Practices for Troubled Mortgages Following the Financial Crisis." Federal Reserve Bank of Chicago Working Paper 2011-03.

Anderson, S., Kogler, B., and Kim, D. (2012). "Loan Modification Performance: A Multivariate Review Approach." *Journal of Structured Finance,* 18(2), pp. 33–49.

Calem, P. S., and Sarama, R. F. (2017). "Why Mortgage Borrowers Persevere: An Explanation of First and Second Lien Performance Mismatch." *Real Estate Economics,* 45(1), pp. 28-74.

Collins, J. M., and Schmeiser, M.D. (2013). "The Effects of Foreclosure Counseling for Distressed Homeowners." *Journal of Policy Analysis and Management*, 32(1), pp. 83–106.

Consumer Financial Protection Bureau (2013). "Mortgage Servicing Rules Under the Truth in Lending Act (Regulation Z), 12 C.F.R. §1026.

Cordell, L., Dynan, K., Lehnert, A., Liang, N., and Mauskopf, E. (2009). "The Incentives of Mortgage Servicers: Myths and Realities." Divisions of Research & Statistics and Monetary Affairs, Federal Reserve Board Working Paper 2008-46.

Cordell, L., Dynan, K., Lehnert, A., Liang, N., Mauskopf, E., and Kolb, R. W. (2011). "The Incentives of Mortgage Servicers and Designing Loan Modifications to Address the Mortgage Crisis." In R. W. Kolb, ed., *Lessons from the Financial Crisis: Causes, Consequences, and Our Economic Future*, Franklin Township, NJ: Wiley, pp. 231–237.

Das, S. R. (2012). "The Principal Principle." *Journal of Financial and Quantitative Analysis*, 47(06), pp. 1215–1246.

Ding, L., Quercia, R., Li, W., and Ratcliffe, J. (2011). "Risky Borrowers or Risky Mortgages Disaggregating Effects Using Propensity Score Models. *Journal of Real Estate Research*, 33(2), pp. 245–277.

Goodman, L. S., Ashworth, R., Landy, B., and Yang, L. (2011). "Modification Success — What Have We Learned?" *The Journal of Fixed Income*, 21(2), p. 57.

Goodman, L. S., Ashworth, R., Landy, B., and Yang, L. (2012). "Mortgage Modification Activity — Recent Developments." *The Journal of Fixed Income*, 21(4), p. 55.

Goodman, L. S., Yang, L., Ashworth, R., and Landy, B. (2013). "Modification Effectiveness: The Private-Label Experience and Its Public Policy Implications." *The Journal of Fixed Income*, 22(3), pp. 21–36.

Guo, S., Barth, R.P., and Gibbons, C. (2006). "Propensity Score Matching Strategies for Evaluating Substance Abuse Services for Child Welfare Clients." *Children and Youth Services Review*, 28, pp. 357–383.

Haughwout, A., Okah, E., and Tracy, J. (2009). "Second Chances: Subprime Mortgage Modification and Redefault." Federal Reserve Bank of New York Staff Report 417.

Jagtiani, J., and Lang, W. W. (2011). "Strategic Defaults on First and Second-Lien Mortgages During the Financial Crisis." *The Journal of Fixed Income,* Spring, pp. 7–23.

Jensen, M. C., and Meckling, W. H. (1976). "Theory of the Firm: Managerial Behavior, Agency Costs, and Ownership Structure." *Journal of Financial Economics,* 3(4), pp. 305–360.

Kingsley, G. T., Smith, R., and Price, D. (2009). "The Impacts of Foreclosures on Families and Communities." Washington, D.C.: The Urban Institute, pp. 757–786.

Mayer, C., Morrison, E., Piskorski, T., and Gupta, A. (2014). "Mortgage Modification and Strategic Behavior: Evidence from a Legal Settlement with Countrywide*." American Economic Review,* 104(9), pp. 2830–2857.

Piskorski, T., Seru, A., and Vig, V. (2010). "Securitization and Distressed Loan Renegotiation: Evidence from the Subprime Mortgage Crisis." *Journal of Financial Economics*, 97(3), pp. 369–397.

Quercia, R., Ding, L., and Ratcliffe, J. (2009). *Loan Modifications and Redefault Risk.* Center for Community Capital, University of North Carolina Chapel Hill Working Paper.

Richter, F., Nelson, L., and Seo, Y. (2010). "Mortgage Delinquencies in Ohio: Are Loan Modifications Stemming the Tide?" Community Development Department of the Federal Reserve Bank of Cleveland Working Paper, https://www.clevelandfed.org/newsroom-and-events/publications/a-look-behind-the-numbers/albtn-20101019-mortgage-delinquencies-in-ohio-are-loan-modifications-stemming-the-tide.aspx.

Rosenbaum, P., and Rubin, D. (1983). "The Central Role of the Propensity Score in Observational Studies for Causal Effects." *Biometrika,* 70, pp. 41–55.

Scharlemann, T., and Shore, S. (2015). "The Effect of Negative Equity on Mortgage Default: Evidence from HAMP PRA." The Office of Financial Research Working Paper 2015-06.

Schmeiser, M., and Gross, M. (2015). "The Determinants of Subprime Mortgage Performance Following a Loan Modification." Finance and Economic Discussion Series 2015-006. Board of Governors of the Federal Reserve System.

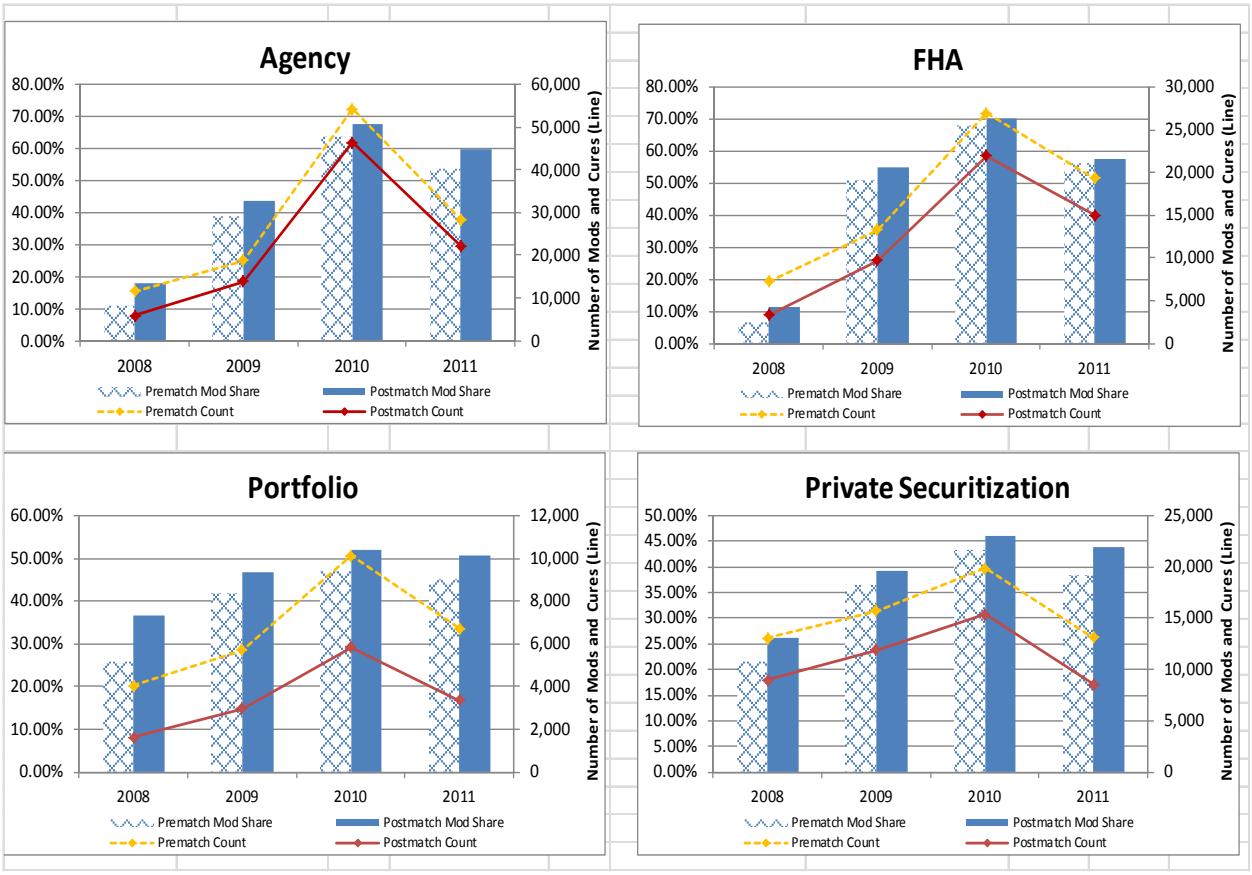
U.S. Department of the Treasury (2009). "Making Home Affordable Program Performance Report," https://www.hud.gov/sites/documents/APRIL2014MHARPTFINAL.PDF.

U.S. Department of the Treasury (July 9, 2012). "The Effect of Principal Reduction on HAMP Early Redefault Rates," https://www.treasury.gov/resource-center/economic-policy/Documents/HAMPPrincipalReductionResearchLong070912FINAL.pdf.

Voicu, I., Been, V., Weselcouch, M., and Tschirhart, A. J. (2011). "Performance of HAMP versus Non-HAMP Loan Modifications — Evidence from New York City." *NYU Law and Economics Research Paper*, pp. 11–41.

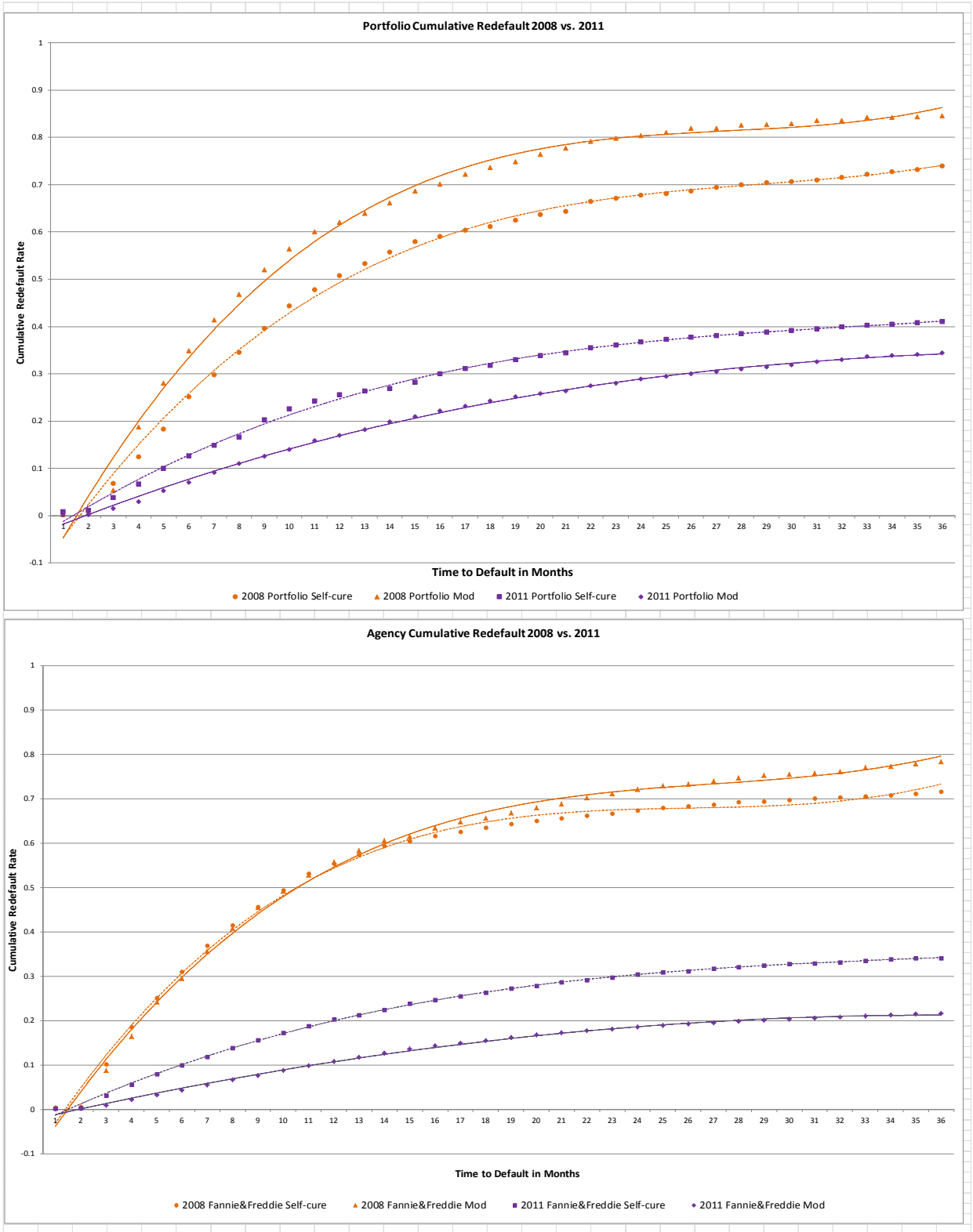
Figure 1: Cure Type by Year of Cure/Modification (Prematch Sample)

Share of Modifications and Total Counts of Modifications and Self-Cures



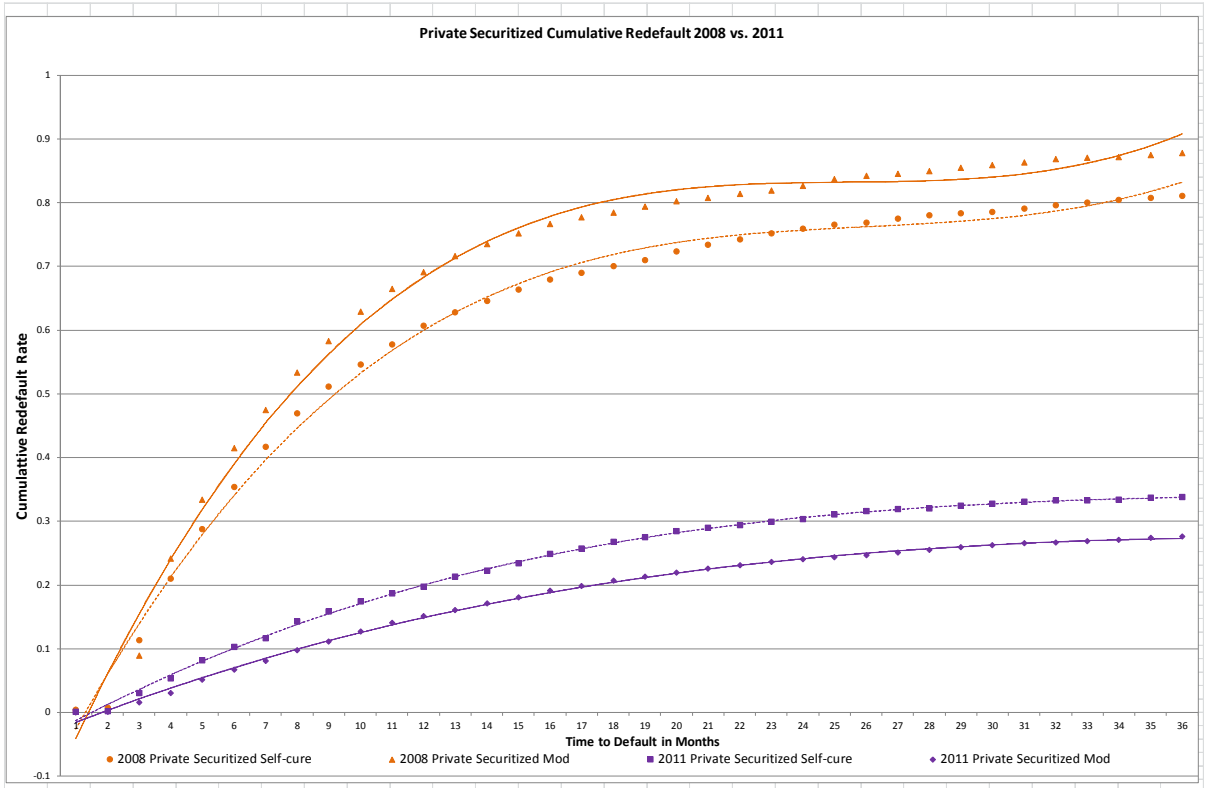
Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc.

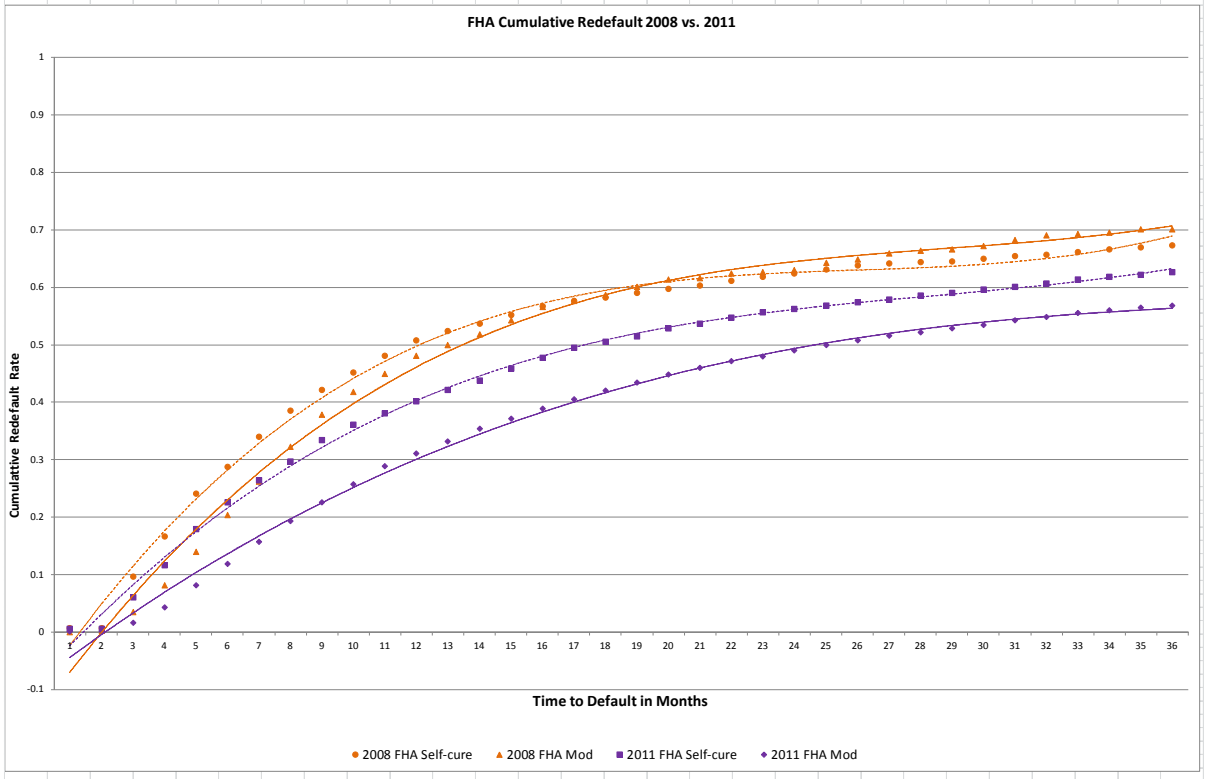
Figure 2: Redefault Rate Comparisons by Investor or Guarantor Category



Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc.

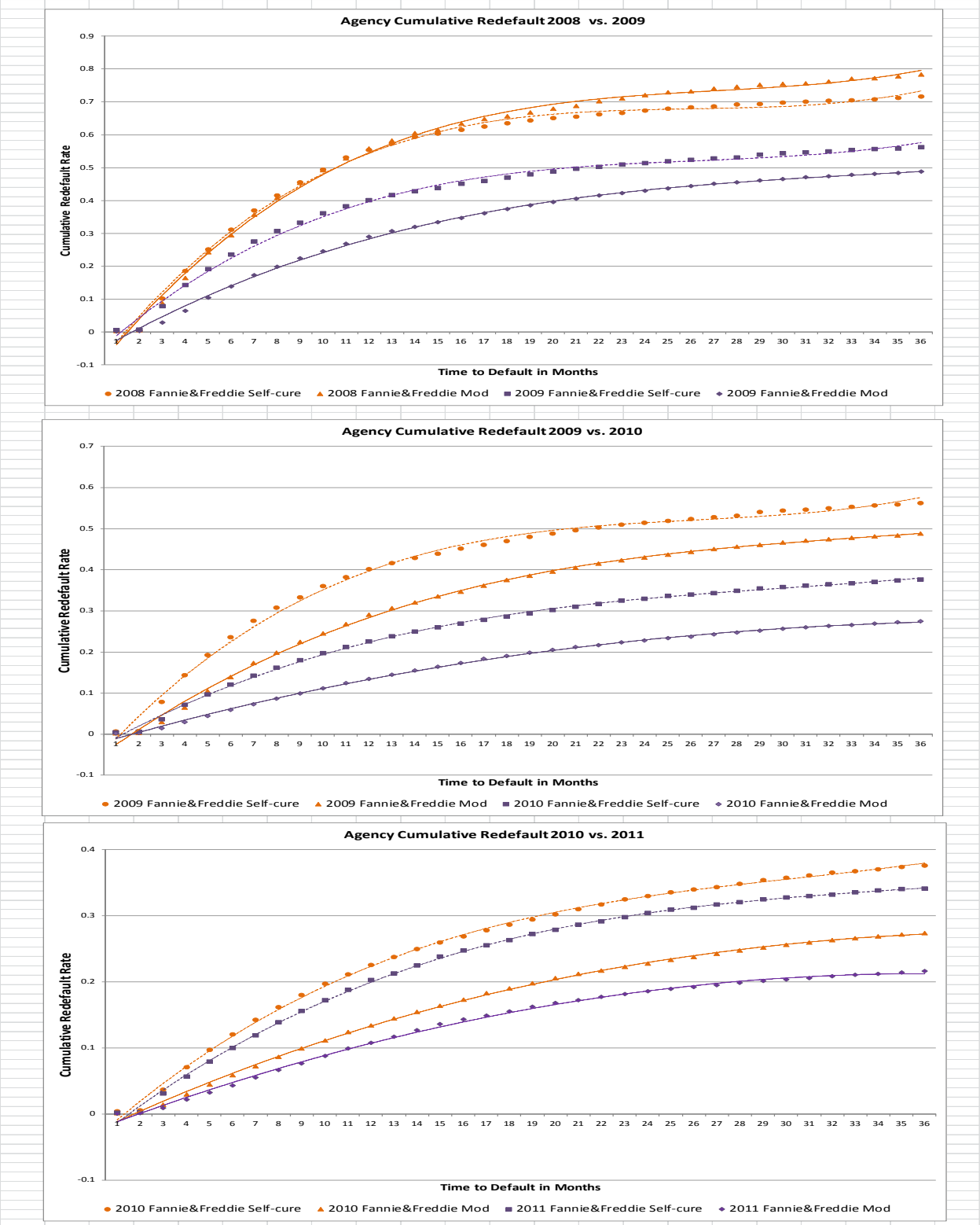
Figure 2 (continued): Redefault Rate Comparisons by Investor or Guarantor Category





Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc.

Figure 3: Redefault Rate Comparisons by Year of Cure for Agency Loans



Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc.

Table 1: Percent of Modifications with Principal Reduction, by Year of Modification and Investor or Guarantor Category (Prematch Sample)

	Agency	FHA	Portfolio	Private Securitized
2008	1.5	2.7	2.4	1.7
2009	2.8	0.4	4.6	4.1
2010	6.1	1.6	4.7	7.3
2011	10.4	4.0	11.7	17.8

Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc.

Table 2. Prematch Sample Mean Values

Year of Cure	Cure Type	Bankruptcy indicator	Indicator for CLTV > 80 and ≤ 90	Indicator for CLTV > 90 and ≤ 100	Indicator for CLTV > 100	Principal Balance	Indicator for cure from ≥ 120 and < 180	Indicator for cure from ≥ 180 and < 270	Indicator for cure from ≥ 270 and < 360	Indicator for cure from ≥ 360
FHA/VA										
2008	Self-cured	3.7%	21.2%	46.4%	4.5%	92,825	25.7%	16.5%	5.4%	2.9%
2008	Modified	0.0%	18.8%	55.5%	8.4%	109,000	42.2%	30.9%	9.2%	2.5%
2009	Self-cured	4.1%	23.2%	47.1%	4.1%	99,255	21.1%	14.5%	5.4%	2.8%
2009	Modified	0.7%	20.4%	56.5%	5.9%	124,264	34.8%	33.1%	12.1%	7.5%
2010	Self-cured	4.1%	24.5%	45.5%	3.3%	110,415	19.6%	13.7%	6.8%	5.2%
2010	Modified	1.2%	22.2%	54.2%	5.0%	129,591	24.6%	27.6%	18.5%	16.2%
2011	Self-cured	4.3%	23.6%	46.4%	3.6%	116,368	19.6%	11.6%	5.7%	4.9%
2011	Modified	1.7%	23.9%	52.8%	3.4%	133,875	23.8%	25.2%	18.0%	19.1%
Agency										
2008	Self-cured	2.6%	16.2%	14.7%	2.2%	117,672	31.0%	16.4%	4.1%	1.6%
2008	Modified	0.2%	24.9%	25.0%	4.7%	167,140	38.9%	26.8%	7.7%	4.9%
2009	Self-cured	3.3%	15.6%	11.8%	1.5%	126,295	28.9%	17.9%	5.8%	2.5%
2009	Modified	0.6%	18.2%	18.3%	2.0%	174,714	32.4%	31.3%	14.5%	7.7%
2010	Self-cured	2.9%	14.7%	8.8%	0.6%	148,275	25.9%	18.7%	9.4%	7.7%
2010	Modified	1.0%	16.1%	15.1%	0.9%	186,811	26.9%	29.4%	16.3%	14.9%
2011	Self-cured	4.1%	13.0%	6.2%	0.7%	136,164	24.9%	16.4%	8.6%	9.9%
2011	Modified	2.2%	15.8%	10.2%	0.8%	181,075	22.3%	25.9%	18.6%	23.4%
Portfolio or Private Securitized										
2008	Self-cured	2.0%	33.5%	14.4%	1.9%	163,971	28.3%	19.7%	7.6%	3.7%
2008	Modified	0.6%	36.3%	18.0%	2.2%	181,463	30.4%	26.9%	12.5%	8.3%
2009	Self-cured	2.9%	31.8%	12.6%	2.1%	187,462	27.5%	19.6%	9.2%	5.8%
2009	Modified	1.1%	30.2%	17.9%	3.3%	198,539	30.5%	27.4%	14.0%	9.8%
2010	Self-cured	3.0%	27.3%	9.5%	2.0%	214,014	21.7%	20.3%	13.0%	13.8%
2010	Modified	1.3%	23.0%	14.6%	3.8%	204,708	23.2%	27.3%	18.0%	20.3%
2011	Self-cured	4.5%	23.9%	9.5%	3.6%	191,598	21.6%	18.1%	11.6%	15.3%
2011	Modified	2.6%	19.8%	13.2%	5.3%	200,911	21.8%	24.6%	17.8%	24.2%

Year of Cure	Cure Type	Indicator for 2 or more first-lien mortgages	Indicator for originated via retail channel	Equifax Risk Score	Current interest rate spread	Subprime indicator	indicator for 1-, 2-, or 3-year ARM	1-year % change county HPI	Jumbo Mortgage Indicator	
FHA/VA										
2008	Self-cured	5.8%	25.5%	507	2.67	40.7%		-8.0%		
2008	Modified	4.1%	23.6%	488	3.04	61.5%		-8.4%		
2009	Self-cured	6.2%	26.4%	519	3.20	40.1%		-7.7%		
2009	Modified	4.5%	23.6%	499	3.36	56.5%		-7.2%		
2010	Self-cured	6.0%	26.6%	527	2.72	35.6%		-2.4%		
2010	Modified	4.6%	20.8%	512	3.03	43.7%		-2.7%		
2011	Self-cured	5.3%	26.9%	531	2.79	27.2%		-3.6%		
2011	Modified	3.9%	23.5%	521	3.14	36.0%		-3.9%		
Agency										
2008	Self-cured	17.6%	30.7%	539	2.69	18.7%	16.8%	-9.9%		
2008	Modified	20.0%	32.8%	520	2.96	20.3%	11.8%	-13.7%		
2009	Self-cured	18.7%	33.9%	551	3.23	16.0%	12.8%	-9.3%		
2009	Modified	17.8%	29.4%	548	3.33	17.8%	7.0%	-9.7%		
2010	Self-cured	17.9%	35.7%	574	2.80	11.4%	8.4%	-2.4%		
2010	Modified	15.0%	29.0%	581	3.05	12.5%	12.0%	-2.7%		
2011	Self-cured	17.4%	37.9%	569	3.04	11.6%	6.4%	-3.7%		
2011	Modified	14.8%	34.8%	580	3.35	10.1%	6.1%	-3.9%		
Portfolio or Private Securitized										
2008	Self-cured	23.5%	23.6%	525	4.45	50.4%	69.5%	-12.6%	13.4%	
2008	Modified	24.4%	14.9%	516	4.98	59.2%	76.1%	-14.2%	13.2%	
2009	Self-cured	25.5%	26.5%	542	4.31	35.5%	52.4%	-11.7%	19.4%	
2009	Modified	21.3%	25.9%	535	4.78	41.5%	67.5%	-12.2%	16.0%	
2010	Self-cured	22.0%	26.2%	560	3.35	29.3%	42.4%	-1.6%	26.5%	
2010	Modified	17.0%	29.0%	553	3.95	35.5%	60.7%	-2.2%	18.6%	
2011	Self-cured	18.7%	26.1%	562	3.37	32.1%	35.5%	-3.5%	23.9%	
2011	Modified	14.4%	29.9%	564	3.92	34.0%	52.1%	-3.8%	19.8%	

Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc.

Table 3. Logistic Regression Model Predicting Propensity Scores

Dependent variable	FHA		GSE		Private Securitized/Portfolio	
Modification						
Independent variable	Coef.		Coef.		Coef.	
Refreshed LTV 80-90 (3 months prior to cure)	0.21091***	(0.03046)	0.21187***	(0.01786)	0.16943***	(0.01928)
Refreshed LTV 90-100 (3 months prior to cure)	0.37825***	(0.02890)	0.45085***	(0.02081)	0.29584***	(0.02366)
Refreshed LTV 100+ (3 months prior to cure)	0.29693***	(0.05026)	0.42638***	(0.05796)	0.42913***	(0.03895)
12 month % change in HPI	0.55536**	(0.22169)	-0.67036***	(0.15503)	-0.89372***	(0.15286)
Subprime	0.18078***	(0.01996)	-0.05268***	(0.01996)	0.00933	(0.01826)
Retail	-0.10580***	(0.02063)	-0.13448***	(0.01408)	-0.07835***	(0.01866)
Bankruptcy status (3 months prior to cure)	-0.94695***	(0.06182)	-0.59724***	(0.04462)	-0.53463***	(0.05260)
Multiple first mortgage	-0.29027***	(0.04375)	-0.20774***	(0.01849)	-0.09683***	(0.02186)
Amortizing ARM					-2.78290***	(0.02974)
Option ARM					-2.76772***	(0.03610)
One year ARM					1.37773***	(0.12917)
Two/Three year Arm					0.61600***	(0.03211)
Log balance amount (3 months prior to cure)	0.82222***	(0.02373)	0.54452***	(0.01528)	0.58349***	(0.02041)
Jumbo					8.50866***	(0.97222)
Portfolio					0.12445***	(0.01916)
Jumbo * Log balance amount (3 months prior to cure)					-0.67121***	(0.07429)
10-year treasury interest rate spread (3 months prior to cure)	0.63235***	(0.01725)	0.42532***	(0.00898)	0.21443***	(0.00553)
Risk score (3 months prior to cure)	-0.00054***	(0.00011)	0.00079***	(0.00007)	0.00031***	(0.00009)
120 to 180 dpd (month prior to cure)	1.12233***	(0.02443)	0.69108***	(0.02006)	0.51485***	(0.02496)
180 to 270 dpd (month prior to cure)	1.53104***	(0.02603)	1.14171***	(0.02096)	0.85391***	(0.02581)
270 to 360 dpd (month prior to cure)	1.80901***	(0.03166)	1.30212***	(0.02441)	1.01635***	(0.02911)
360 to 540 dpd (month prior to cure)	1.81684***	(0.03326)	1.39490***	(0.02469)	1.13165***	(0.02861)
N	75,970		123,565		97,888	
C Statistic	0.81		0.769		0.818	
Pseudo R-squared	0.3768		0.3013		0.3681	

The dependent variable is a loan receiving a loan modification. Models include state fixed effects, year of origination controls, and year-quarter of cure controls. Results are robust to the inclusion of state fixed effects. The ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are calculated without addtional adjustments.

Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc. DPD = days past due

Table 4. Match Statistics

Panel A: Percent of Modifications with at Least One Matched Self-Cure

	GSEs	FHA	Portfolio	Private Securitized
2008	61.4%	73.8%	43.1%	59.7%
2009	60.9%	72.5%	46.4%	59.3%
2010	67.3%	77.8%	53.5%	60.9%
2011	64.5%	73.7%	46.9%	55.2%

Panel B: Percent of Self-Cures with at Least One Matched Modification

	GSEs	FHA	Portfolio	Private Securitized
2008	26.8%	29.6%	19.4%	37.5%
2009	38.0%	43.1%	26.4%	40.5%
2010	41.7%	49.7%	31.6%	42.7%
2011	37.8%	48.5%	26.6%	34.7%

Panel C: Frequency Distribution for Multiple Matches

Investor/Guarantor	Number of Matches	2008	2009	2010	2011
GSEs	1	9.9%	10.8%	5.0%	9.6%
	2 or 3	13.6%	18.2%	17.8%	20.9%
	4 or 5	10.3%	14.5%	24.9%	21.6%
	6 or More	66.2%	56.5%	52.2%	47.9%
FHA	1	4.6%	14.8%	10.7%	17.8%
	2 or 3	10.3%	27.4%	28.4%	27.2%
	4 or 5	7.5%	19.7%	28.1%	20.3%
	6 or More	77.6%	38.1%	32.8%	34.6%
Portfolio or Private Securitized	1	15.2%	18.56%	19.35%	22.08%
	2 or 3	20.5%	24.4%	27.5%	25.0%
	4 or 5	14.4%	14.7%	19.0%	15.0%
	6 or More	49.9%	42.4%	34.1%	37.9%

Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc.

Table 5: Postmatch Sample Mean Values

Year of Cure	Cure Type	Bankruptcy indicator	Indicator for CLTV > 80 and ≤ 90	Indicator for CLTV > 90 and ≤ 100	Indicator for CLTV > 100	Principal Balance	Indicator for cure from ≥ 120 and < 180	Indicator for cure from ≥ 180 and < 270	Indicator for cure from ≥ 270 and < 360	Indicator for cure from ≥ 360
FHA/VA										
2008	Self-cured	1.4%	21.1%	61.2%	6.5%	106,778	41.4%	30.9%	7.8%	1.3%
2008	Modified	0.0%	21.2%	60.3%	9.0%	108,609	41.5%	31.2%	7.9%	1.3%
2009	Self-cured	1.0%	22.8%	63.8%	4.1%	126,933	36.5%	33.9%	10.5%	5.6%
2009	Modified	0.6%	22.0%	62.1%	6.6%	126,300	36.4%	33.6%	10.6%	6.0%
2010	Self-cured	1.2%	23.0%	60.1%	4.6%	135,129	25.3%	27.8%	17.9%	15.1%
2010	Modified	1.1%	23.2%	60.2%	5.6%	133,819	25.2%	27.7%	18.0%	15.6%
2011	Self-cured	1.3%	23.6%	60.8%	4.5%	141,690	25.7%	25.1%	17.3%	16.8%
2011	Modified	1.5%	25.0%	58.1%	3.7%	136,227	25.8%	25.0%	17.3%	17.2%
Agency										
2008	Self-cured	1.2%	19.8%	26.7%	4.2%	146,771	42.6%	24.2%	6.4%	2.8%
2008	Modified	0.2%	26.3%	31.6%	5.9%	164,775	42.6%	24.6%	6.3%	3.1%
2009	Self-cured	1.2%	17.9%	18.5%	2.4%	162,711	34.9%	32.1%	12.9%	4.9%
2009	Modified	0.6%	19.9%	21.8%	2.5%	175,567	34.8%	32.1%	13.1%	4.8%
2010	Self-cured	1.2%	17.2%	15.3%	0.8%	171,557	27.4%	29.4%	16.2%	14.4%
2010	Modified	1.0%	18.9%	18.9%	1.1%	189,073	27.3%	29.6%	16.1%	14.7%
2011	Self-cured	1.5%	15.8%	10.0%	0.9%	169,547	22.4%	26.3%	17.8%	23.4%
2011	Modified	2.3%	18.5%	12.1%	0.9%	183,924	22.4%	26.2%	17.9%	23.5%
Portfolio or Private Securitized										
2008	Self-cured	1.0%	35.8%	18.8%	2.6%	184,756	31.4%	26.5%	11.5%	6.6%
2008	Modified	0.4%	38.6%	20.9%	2.1%	185,190	31.6%	26.6%	11.5%	6.4%
2009	Self-cured	1.1%	28.8%	18.3%	4.1%	201,190	32.1%	28.5%	12.2%	8.0%
2009	Modified	1.0%	31.7%	19.2%	3.5%	204,658	32.3%	28.4%	12.2%	8.3%
2010	Self-cured	1.4%	25.9%	14.4%	2.6%	205,913	25.7%	27.2%	15.6%	19.9%
2010	Modified	1.2%	24.9%	15.5%	3.8%	208,533	25.5%	27.3%	15.7%	19.9%
2011	Self-cured	1.8%	22.8%	13.7%	5.6%	194,797	22.7%	24.2%	16.2%	25.0%
2011	Modified	2.5%	23.0%	15.1%	5.7%	207,010	22.6%	24.1%	16.2%	24.8%

year of cure	Cure Type	Indicator for 2 or more first-lien mortgages	Indicator for originated via retail channel	Consumer Credit Score	Current interest rate spread	Subprime indicator	indicator for 1-, 2-, or 3-year ARM	1-year % change county HPI	Jumbo Mortgage Indicator	Estimated propensity score
FHA/VA										
2008	Self-cured	4.4%	25.3%	499	2.64	51.1%		-8.1%		7.6%
2008	Modified	3.4%	23.0%	485	3.02	63.8%		-8.3%		9.9%
2009	Self-cured	3.9%	22.0%	507	3.28	48.4%		-7.2%		68.2%
2009	Modified	3.8%	22.7%	500	3.34	57.7%		-7.2%		70.1%
2010	Self-cured	3.9%	22.8%	514	2.89	41.4%		-2.6%		78.4%
2010	Modified	4.1%	20.2%	513	3.03	44.2%		-2.7%		80.4%
2011	Self-cured	3.9%	24.1%	522	2.95	34.1%		-3.7%		69.4%
2011	Modified	3.5%	23.3%	523	3.11	35.8%		-3.9%		71.5%
Agency										
2008	Self-cured	14.4%	25.2%	541	2.85	21.9%	5.9%	-12.6%		21.6%
2008	Modified	16.8%	31.7%	520	2.99	24.1%	7.4%	-12.7%		22.9%
2009	Self-cured	15.6%	30.8%	556	3.32	21.0%	11.8%	-9.5%		49.8%
2009	Modified	16.1%	28.1%	552	3.35	20.1%	6.2%	-9.6%		51.7%
2010	Self-cured	13.8%	31.7%	578	3.05	14.5%	7.4%	-2.7%		68.8%
2010	Modified	13.7%	27.9%	583	3.09	13.5%	11.7%	-2.7%		71.3%
2011	Self-cured	13.8%	32.9%	580	3.38	13.7%	2.9%	-3.9%		63.5%
2011	Modified	13.7%	33.8%	586	3.37	10.9%	4.0%	-3.9%		65.1%
Portfolio or Private Securitized										
2008	Self-cured	20.8%	22.2%	524	4.69	59.2%	78.5%	-14.9%	11.9%	24.7%
2008	Modified	23.0%	14.2%	519	5.05	62.9%	78.6%	-14.9%	12.6%	25.2%
2009	Self-cured	21.8%	30.7%	538	4.58	43.6%	68.1%	-12.9%	16.2%	55.5%
2009	Modified	19.4%	27.2%	539	4.75	44.7%	70.8%	-12.9%	15.7%	57.0%
2010	Self-cured	18.3%	26.3%	554	3.78	35.4%	63.7%	-2.2%	18.2%	65.6%
2010	Modified	16.2%	29.4%	557	3.93	36.9%	65.2%	-2.2%	18.1%	66.9%
2011	Self-cured	14.8%	24.8%	561	3.82	37.8%	46.2%	-3.8%	16.9%	60.7%
2011	Modified	14.2%	31.2%	569	3.87	32.7%	50.5%	-3.8%	20.2%	61.6%

Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc.

Table 6: Postmatch Sample Mean Values

Panel A: Principal reduction dummy indicator

Year of Modification	FHA/VA	Agency	Private Securitized or Portfolio
2008	2.12%	1.40%	1.94%
2009	0.30%	3.13%	4.32%
2010	1.63%	6.38%	6.61%
2011	4.43%	11.10%	16.69%

Panel B-: Mean values for size of payment reduction

Year of modification	FHA/VA	Agency	Private Securitized or Portfolio
2008	6.47%	23.73%	24.26%
2009	10.79%	31.92%	30.02%
2010	14.07%	40.99%	37.20%
2011	17.65%	38.44%	39.55%

Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc.

Table 7. Logistic Regression Model for Redefault of Self-Cured Loans

	Agency		Portfolio	
Redefault within 36 months of cure				
Independent Variables	*Coefficient*		*Coefficient*	
Cured 2009Q2-Q4	-0.58109***	(0.06286)	-0.40790***	(0.05957)
Cured 2010	-1.16871***	(0.05863)	-1.13664***	(0.05769)
Cured 2011	-1.15007***	(0.06139)	-1.31083***	(0.06301)
Portfolio loan			0.03535	(0.03003)
Change in unemployment rate 1-18 months after cure (+)	0.03151**	(0.01559)	0.04394**	(0.01793)
Change in unemployment rate 1-18 months after cure (-)	0.00772	(0.00899)	0.02463*	(0.01471)
% Change in HPI 1-18 months after cure (+)	-2.10504***	(0.18453)	-1.51378***	(0.27612)
% Change in HPI 1-18 months after cure (-)	-1.54134***	(0.27331)	-2.61344***	(0.38027)
Refreshed LTV 80-90 (3 months prior to cure)	0.16210***	(0.02348)	0.19452***	(0.03059)
Refreshed LTV 90-100 (3 months prior to cure)	0.29797***	(0.02582)	0.42100***	(0.03876)
Refreshed LTV > 100 (3 months prior to cure)	0.45160***	(0.08136)	0.85899***	(0.06695)
Log balance (3 months prior to cure)	0.03057*	(0.01674)	0.01143	(0.02151)
Risk score (3 months prior to cure)	-0.00266***	(0.00009)	-0.00347***	(0.00015)
Subprime	0.35813***	(0.02427)	0.19791***	(0.02826)
Multiple first mortgage	0.11303***	(0.02530)	0.07651**	(0.03457)
Bankruptcy status (3 months prior to cure)	-0.17165**	(0.07322)	0.01787	(0.10090)
Cure from 180-269 DPD	0.05905***	(0.02185)	-0.04608	(0.03275)
Cure from 270+ DPD	0.18464***	(0.02123)	0.02597	(0.03141)
N	416938		205878	
C Statistic	0.649		0.742	
Observations are weighted using the matched-sample weights. The ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are calculated without addtional adjustments.				

Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc. DPD = days past due

Table 8. Logistic Regression Model for Redefault of Modified Loans

	Agency: Model 1		Agency: Model 2		Private Securitized or Portfolio: Model 1		Private Securitized or Portfolio: Model 2	
Dependent Variable			Restricted to 120+ DPD at Modification				Restricted to 120+ DPD at Modification	
Redefault within 36 months of modification								
Independent Variables	*Coefficient*		*Coefficient*		*Coefficient*		*Coefficient*	
Self-cure redefault probability	1.1453***	(0.0626)	1.1095***	(0.0676)	0.988***	(0.0539)	0.934***	(0.0580)
Modified 2009Q2-Q4	-0.3152***	(0.1101)	-0.3136***	(0.1246)	-0.4294***	(0.0911)	-0.5337***	(0.1059)
Modified 2010	-0.2591**	(0.1261)	-0.2758*	(0.1441)	-0.3756***	(0.1098)	-0.4812***	(0.1284)
Modified 2011	-0.4608***	(0.1282)	-0.488***	(0.1455)	-0.5884***	(0.1183)	-0.7024***	(0.1363)
Portfolio loan					-0.097*	(0.0520)	-0.1245**	(0.0574)
Change in unemployment rate 1-18 months after cure (+)	0.0378	(0.0343)	0.0341	(0.0376)	0.0455	(0.0277)	0.0426	(0.0311)
Change in unemployment rate 1-18 months after cure (-)	0.0246	(0.0217)	0.0339	(0.0231)	0.0143	(0.0267)	0.0171	(0.0269)
% Change in HPI 1-18 months after cure (+)	0.1737	(0.4715)	0.2258	(0.5129)	-1.2562***	(0.4751)	-1.2558**	(0.5125)
% Change in HPI 1-18 months after cure (-)	-0.2398	(0.6437)	-0.1812	(0.6858)	0.7104	(0.6433)	0.6746	(0.7041)
Principal modification	-0.3415***	(0.0334)	-0.3515***	(0.0328)	-0.2634***	(0.0372)	-0.2948***	(0.0383)
Payment change spline (<15%)	-5.1648***	(0.3344)	-5.1165***	(0.3487)	-3.1201***	(0.4068)	-2.8333***	(0.4401)
Payment change spline (>15%)	3.606***	(0.3700)	3.5826***	(0.3813)	1.0472***	(0.4561)	0.7576	(0.4946)
Modified from 180-269 DPD	0.2659	(0.0480)	0.1825***	(0.0514)	0.3828***	(0.0528)	0.3072***	(0.0572)
Modified from 270+ DPD	0.4259	(0.0518)	0.3464***	(0.0549)	0.6484***	(0.0525)	0.5724***	(0.0596)
N	60926		54961		28330		24864	
C Statistic	0.723		0.718		0.791		0.789	

Observations are weighted using the matched-sample weights. The ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are calculated via a bootstrap to address the estimated regressor problem.

Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc. DPD = days past due

Table 9: Odds Ratios Associated with Modification Vintage Dummies (Model 1)

Modification Vintage	Agency	Private Securitized or Portfolio
2009 Q2-Q4	0.730	0.651
2010	0.772	0.687
2011	0.631	0.555

Sources: Equifax Credit Risk Insight Servicing McDash and McDash Analytics, LLC, a wholly owned subsidiary of Black Knight, Inc.