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Credit History and the Performance of Prime and Nonprime Mortgages*

By Anthony Pennington-Cross

Although nonprime lending has experienced steady or even explosive growth over the last decade very little is known about the performance characteristics of these mortgages.

Using data from national secondary market institutions, this paper estimates a competing risks proportional hazard model, which includes unobserved heterogeneity. The analysis examines the performance of 30-year fixed rate owner occupied home purchase mortgages from February 1995 to the end of 1999 and compares nonprime and prime loan default and prepayment behavior. Nonprime loans are identified by mortgage interest rates that are substantially higher than the prevailing prime rate.

Results indicate that nonprime mortgages differ significantly from prime mortgages: they have different risk characteristics at origination; they default at elevated levels; and they respond differently to the incentives to prepay and default. For instance, nonprime mortgages are less responsive to how much the option to call the mortgage or refinance is in the money and this effect is magnified for mortgages with low credit scores. Tests also reveal that default rates are less responsive to homeowner equity when credit scores are included in the specification.

1. Introduction

In recent years traditional mortgage market participants have made a concerted effort to increase lending to nonprime borrowers, that is, borrowers who may not qualify for conventional loans, These borrowers typically pay higher origination fees and interest rates to reflect the higher potential risk of default and prepayment. Data on the performance of nonprime loans are sparse. While some private companies (for instance, the Mortgage Information Corporation and University Financial Associates) publish summary statistics indicating that nonprime loans prepay and default at substantially higher rates than prime loans, little is known about why this occurs.

Using a competing risk framework that allows for unobserved individual borrower heterogeneity this paper examines the performance (default and prepay probabilities and termination rates) of prime and nonprime loans that were originated from February 1995 through February 1998. The simple average from the sample indicates that nonprime mortgages are six

times more likely to default and 1.3 times more likely to prepay than prime mortgages. In addition, the model results indicate that nonprime loans prepay less frequently than prime loans when interest rates drop substantially and make it financially advantageous to prepay.

2. Background on Nonprime Loans

Most research and commentary on nonprime lending has relied on a list of lenders provided by the Department of Housing and Urban Development (HUD). This list consists of lenders identified by HUD as being mainly "subprime" lenders from trade magazines and publications. HUD's list is then applied to an existing database that identifies the lender, such as the Home Mortgage Disclosure Act data set. This data has been used by HUD to show that, at least for refinance loans, subprime lenders tend to be the primary form of mortgage financing used in many lower income and minority census tracts (HUD 2000). In addition, Canner and Passmore (1999) found that reports of increasing application rejection rates through the 1990s were associated with the growing share of applications to subprime lenders. In contrast, Pennington-Cross and Yezer (2000) showed that the subprime market niche for home purchase mortgages is not low income, low wealth, minority households, but instead households with substantial wealth to help compensate for other weaknesses in the loan application.

Private corporations, such as University Financial Associates LLC (UFA), have examined the sensitivity of loans with low credit scores to stressful economic conditions. They find that low credit score loans default at twice the rate of high credit score loans in both good and bad economic conditions. 1 In addition, the Mortgage Information Corporation (MIC) reports that for the nation as a whole subprime loans are seriously delinquent (90 days or more delinquent or in foreclosure) approximately 7.76 times more often than prime mortgages and prepay 1.21 times as fast as prime mortgages (MIC, *The Market Pulse* Winter, 2002), which is very similar to the simple average from the sample used in this study.

UBS Warburg (2002) has also proposed that elevated levels of prepayment for subprime loans are primarily caused by credit curing. Credit curing relies on the ability of borrowers with poor credit history to become better at managing their finances once they have a mortgage. Other alternative explanations include the possibility that (i) subprime borrowers learn that they could have gotten a cheaper mortgage and therefore refinance, (ii) subprime loans are more responsive to decreasing interest rates due to their higher cost of debt servicing, or (iii) subprime borrowers are more likely to experience financial hardship and use homeowner equity through cash out refinancing to help smooth consumption patterns.

3. Prime and Nonprime Comparison

This paper uses data on fixed rate single-family owner occupied home purchase mortgages from two national secondary market participants. The interest rate at origination is used to identify which loans should be characterized as nonprime. Loans are categorized as high interest rate if the contract rate at origination is 100 basis points greater than the monthly rate reported by Primary Mortgage Market Survey by Freddie Mac.[2] The advantage of this approach is that it allows the market place to identify the riskiness of the loan through the price being charged rather than a list of lenders who may originate a heterogeneous set of mortgage products. The identification of a loan as having a high interest rate does not by itself indicate that the loan is actually a greater lending risk, because many other factors can affect the overall riskiness of a mortgage and the interest rate. It only indicates that the particular loan pays a higher interest rate. Restricting the sample to 30 year fixed rate home purchase loans originated from February of 1995 through February of 1998 provides an initial sample of 65,992 nonprime loans, which may be studied through the end of 1999 with respect to default, prepayment, and survival. For comparison purposes, 24,018 prime loans are sampled during the same time period. Models are estimated for each group and the results are compared.

Before examining model results, it is useful to look at the general characteristics of this data. Table 1 shows means and standard deviations of loan characteristics at origination and by termination type. In general, the data show that nonprime loans look much different at origination and perform differently on average than prime loans. For instance, nonprime FICO credit scores are almost 40 points lower and down payments are 6.7 percentage points higher. Given these characteristics it should be no surprise that nonprime loans default (# defaults/#loans = 3,062/65,992 = 4.64%) much more often than prime loans ((# defaults/#loans = 185/24,018 = 0.77%).

For both nonprime and prime loans, Table 1 shows that loans that default tend to have lower credit scores, smaller down payments, and pay higher interest rates. In addition, prime loans that prepay are on average 7.3 percent in the money, while nonprime loans that prepay are on average 5.9 percent in the money.

3.1. Caveats

The results of this paper cannot necessarily be generalized for the entire subprime mortgage market because (i) only whole loan 30-year-fixed rate owner occupied home purchase purchases by two national secondary market participants are included; (ii) the two market participants do not reflect the entire subprime market, but instead are more likely to include the

least risky portion such as A- and Alt-A loans; (iii) the time period covered is one of unusually strong economic growth; (iv) the loans may have characteristics that are specific only to the institutions included and the servicers of the mortgages; and (iv) important segments of the mortgage market such as Veterans Administration, Federal Housing Authority, and jumbo loans are not included in the analysis because the study examines the performance of only non-government loans that fall within the conventional conforming loan limits.

Given the caveats, it is particularly noteworthy that, even in this narrow portion of the subprime market, which is likely to approximate the characteristics of the prime market more closely than the entire subprime market, there are critical differences in loan performance.

4. Motivations for Prepaying and Defaulting

4.1. Why Prepay?

Mortgages are typically prepaid because the borrower is refinancing or moving. The motivations to refinance are primarily driven by changes in market interest rates or some other event that may require a household to take equity out of the home through a cash out refinance. The motivations to move can be derived from factors such as relocation, change in family structure, or a change in employment conditions or wages. While it is impossible using the data set in this study to separate prepayments between refinances and moves, the majority of prepayments are typically associated with refinances and this will be the focus of the analysis of prepayments.

If the savings from the new mortgage (refinancing) outweigh any transaction costs, changes in interest rates can motivate borrowers to prepay the loan, even if they only received the loan in the last few months. But even when the option to prepay (call the mortgage) is "in the money", not all borrowers will automatically prepay the mortgage. One explanation for the sluggishness of borrower response to the call option is that transaction costs can vary across borrowers so that some borrowers will require the mortgage to be more in the money than others to activate the option. But the ability and desire to refinance can be constrained by other factors than just transaction costs. For instance, it may be difficult to obtain financing if the homeowner has low credit scores, has little or negative equity in the house, or is unemployed or earning substantially less money (Mattey and Wallace, 2001; Green and LaCour-Little, 1997; Peristiana et al., 1997; LaCour-Little, 1997).

Alternatively, some borrowers in need of cash may be more likely to prepay even if the transactions costs are high. In this case, the call option may be "out of the money" but the borrower may decide to refinance anyway, strictly for cash flow maintenance purposes. For

nonprime borrowers credit could be improving over time making it possible to refinance at a lower mortgage cost.

In general, house price dynamics, the credit history of the borrower, interest rate changes and the local unemployment rate should all playa strong role in determining prepayment rates. Since it is impossible to identify all of the potential reasons to prepay or not to prepay, there will be unobserved differences in the propensity of loans to prepay. The estimation procedure needs to address this unobserved individual heterogeneity.

4.2. Why Default?

Home owners can be driven to default by trigger events, such as a loss in income or job, that make it impossible for the household to meet its financial obligations. Therefore, indicators such as the area unemployment rate provide a proxy for some of the trigger events. However, some borrowers are more predisposed before they purchase a home to pay bills on time and to accumulate manageable amounts of debt. This information or the credit history of the borrower is captured by the credit bureau's credit score. Furthermore, when the house is worth less than the outstanding mortgage or is in negative equity the borrower can save financial resources by defaulting. Since there are substantial and persistent costs associated with defaulting, however, it is likely to require a substantial negative equity position for most borrowers to default, thus exercising the put option.

The static view of when it is optimal to default can be misleading. Since a mortgage is paid off using a series of payments, the optimal time to default is best viewed in a dynamic and forward-looking framework. In other words, while it may be in the money to default today from a static point of view the value of defaulting may be larger in the future because house prices may drop even more. Conversely, prices may increase in the future thus increasing the returns of holding on to the house and outweighing the value of defaulting. As a result, it is often optimal to delay a default even if the homeowner is in a negative equity position (Kau and Kim, 1994). Therefore, even ignoring transaction costs or credit history costs associated with defaulting it is likely to require a large negative equity position for a borrower to exercise the option to default. In addition, the more variable house prices are the more likely it is that prices will be lower in the future, thus increasing the value of a future default and increasing the likelihood of delaying the default.

5. The Competing Risk Models

This paper uses a version of the competing risk model introduced by McCall (1996) in a study of unemployment duration and first implemented for mortgages by Deng et al. (2000). Applying this approach to mortgages, borrowers consider the default, prepayment, and continuation of the mortgage as options that affect the duration of the mortgage. The probability of one event is necessarily tied to the others and is estimated jointly using a proportional hazard model with grouped duration data. The outcomes of default and prepayment compete with each other to be the first event to occur (the observed event). In addition, there may be unobserved characteristics associated with the loans that make it more or less likely that the loan will prepay or default. The McCall approach estimates what fraction of the loans in the sample belongs to discrete unobserved types (for example, fast or slow terminators due to unobserved characteristics) and the magnitude of the difference between the groups.

One of the benefits of the McCall approach is that it uses information typically ignored in more traditional models that require independence and separability. Separate models treat all outcomes not included as being censored observations (examples of this approach include Green and Shoven (1986) and Deng (1997). This produces demonstrable effects on estimated coefficients and can result in large type I and II out of sample forecasting errors. Another approach, the multinomial logit specification, assumes outcomes are independent from each other. This produces similar symptoms to the separability assumption and for specific samples may result in inefficient and imprecise estimation. This is commonly referred to as the "independence of irrelevant alternatives assumption."

An alternative approach used by Ambrose and Capone (2000) assumes constant time dependence when estimating the exponential baseline hazard, but then includes more time variables as additional covariates (the age of the loan) to augment the baseline hazard as a multiplicative shift function.

The proportional hazard model as popularized by Deng et al. (2000) and used in a prepayment model by Ambrose and LaCour-Little (2001) is used in this paper.[3] See Appendix B of McCall (1996) for more details on the definition of the likelihood function. In summary, the outcome determines the contribution of the observation to the likelihood, an adjustment factor is used because duration is measured in discrete time, and unobserved individual loan heterogeneity is introduced.

Define the time to prepayment as T_p and the time to default as T_d, which are random variables that have a continuous probability distribution defined as $f(t_w)$, where t_w is a

realization of $T_w(w = p, d)$. The joint survivor function for loan j is then $S_j(t_p, t_d) = \text{pr}(T_p > t_p, T_d > t_d | x_{tj})$. The joint survivor function has the following form:

$$S_j(t_p, t_d) = \exp\left(-\theta_p \sum_{t=0}^{t_p} \exp(\beta_p' x_{jt}) - \theta_d \sum_{t=0}^{t_d} \exp(\beta_d' x_{jt})\right). \quad (1)$$

Note t indexes time in months for outcome p, d, or c which indicates whether the loan is prepaid, defaulted, or continued and j indexes the N individual loans. The baseline hazard function is one element of the matrix x_{jt} and is parameterized by age, and age squared. The coefficients (β_w) can be used to approximate the underlying continuous time baseline hazard for the default and prepayment probabilities. The vector of parameters (β_w) also represents other time varying and time constant effects of regressors on the probability of terminating. θ_p and θ_d represent the effect of unobserved heterogeneity on the probability of prepayment and default respectively. These unobserved effects are allowed to correlate with each other, but are assumed to be jointly independent of x_{jt}. There are two distinct groups that occur in the population of loans with frequency of m_1 and m_2.[4] The 8's provide separate intercepts for each of the four types $(\theta_{p1}, \theta_{p2}, \theta_{d1}, \theta_{d2})$ and the m's indicate how many 1s and 2s there are. Only the shortest mortgage duration is observed, $T_j = \min(T_p, T_d, T_c)$. The hazard probabilities of mortgage prepayment, $A_{pj}(t)$, default $A_{dj}(t)$, unknown $A_{uj}(t)$, or continuing $A_{cj}(t)$ in time period t are defined as:

$$\begin{aligned}
A_{pj}(t|\theta_p, \theta_d) &= S_j(t, t|\theta_p, \theta_d) - S_j(t+1, t|\theta_p, \theta_d) - 0.5\left(S_j(t, t|\theta_p, \theta_d) + S_j(t+1, t+1|\theta_p, \theta_d) - S_j(t, t+1|\theta_p, \theta_d) - S_j(t+1, t|\theta_p, \theta_d)\right) \\
A_{dj}(t|\theta_p, \theta_d) &= S_j(t, t|\theta_p, \theta_d) - S_j(t, t+1|\theta_p, \theta_d) - 0.5\left(S_j(t, t|\theta_p, \theta_d) + S_j(t+1, t+1|\theta_p, \theta_d) - S_j(t, t+1|\theta_p, \theta_d) - S_j(t+1, t|\theta_p, \theta_d)\right) \\
A_{uj}(t) &= S_j(t, t|\theta_p, \theta_d) - S_j(t+1, t+1|\theta_p, \theta_d) \\
A_{cj}(t) &= S_j(t, t|\theta_p, \theta_d). \quad (2)
\end{aligned}$$

The term multiplied by 1/2 is the adjustment made because duration is measured in months instead of continuously. The above expresses the probability of a particular outcome conditioned on observed and unobserved characteristics. The unconditional probability can be expressed by

$$F_z(t) = m_1 A_z(t|\theta_{p1}, \theta_{d1}) + m_2 A_z(t|\theta_{p2}, \theta_{d2}), z = p, d, u, c \quad (3)$$

The sum of the two mass points for the four unobserved components must equal one $(m_1 + m_2 = 1)$. Using the above and taking logs, the likelihood of the proportional competing risks model is summed across all *N* loans.

$$\sum_{j=1}^{N} \delta_{pj} \log\left(F_p(T_j)\right) + \delta_{dj} \log\left(F_d(T_j)\right) + \delta_{uj} \log\left(F_u(T_j)\right) + \delta_{cj} \log\left(F_c(T_j)\right). \quad (4)$$

$\delta_{zj,z} = p, d, u, c$ indicate if the jth loan is terminated by prepayment, default, an unknown reason, or censoring.

5.1. Empirical Specification

The empirical analysis is conducted on fixed rate 30 year owner occupied home purchase nonprime and prime loans. 24,108 prime loans and 65,992 nonprime loans are included in the sample. To determine if it makes sense for the borrower to refinance a mortgage, the present discounted cost (*PDC*) of all future payments for the current mortgage is compared to the *PDC* of all future payments if the borrower refinances. Ignoring transaction costs, if the cost of refinancing is lower than the cost of continuing to pay then the option to refinance or prepay is "in the money." To address the refinance option assume that the borrower can obtain a loan for the remaining term of the original loan, but does so at current market interest rates. The discounted term is assumed to be the 10-year constant maturity Treasury bill reported for each month.

For fixed rate mortgages given the original balance (O), the term of the mortgage (TM), and the interest rate on the mortgage (i), the monthly payments can be calculated for each borrower, j.

$$P_j = i_j * O\left[\frac{(1+i_j)^{TM}}{(1+i_j)^{TM}-1}\right]. \quad (5)$$

The monthly payments (P_j) are constant through the life of the loan and are discounted by d in each month (m) until the mortgage is fully paid in *TM* months:

$$PDC_{jc} = \sum_{m=0}^{TM} \frac{P_j}{(1+d_j)^m}. \quad (6)$$

The PDC_{jc} is then recalculated for each month for each borrower for as long as the loan exists. This process is then repeated for the refinanced mortgage to calculate PDC_{jr} except that the unpaid balance of the current mortgage becomes the original balance in equation (5), the term of the loan (TM) is the remaining term of the original loan, and the interest rate on the

refinanced mortgage is the market rate as defined by the Freddie Mac Primary Mortgage Market Survey in that month. The call option is defined as:

$$refi_{jt} = \left[\frac{(PDC_{jc} - PDC_{jr})}{PDC_{jc}}\right] \quad (7)$$

The variable $refi_{jt}$ is defined as the percentage reduction in the present value of future payments the borrower, j, will gain in time period t if the mortgage is refinanced. This specification of the call option is likely to be a good representation of how much the option to prepay is in the money for prime loans. However, since the market interest rate is a prime rate, the above specification will show all nonprime loans to be in the money—even at the moment of origination. This is due to the higher rate the nonprime loans pay due to deficiencies in the mortgage application. To reflect the credit impairment the market rate used for the refinance option is adjusted up in each month by the fraction that the borrower's contract rate was above the prime contract rate at origination. Therefore, the call option $(refi_{jt})$ will reflect solely changes in interest rates, not differences in the credit worthiness of the borrower. This approach implicitly holds the borrower's credit quality constant.

To determine how loan performance is affected by the equity in the home, the loan to value ratio (ltv_j) is updated in each month to estimate the current loan to value $(ltvc_{jt})$. To calculate $ltvc_{jt}$ the outstanding balance of the mortgage and the value or current price of the house must be updated through time. The unpaid balance of the mortgage is calculated assuming that payments are received on time, and the house price is updated using the Office of Federal Housing and Enterprise Oversight (OFHEO) repeat sales price index at the metropolitan area level. But since the actual value of the home is estimated, not observed, it may be more accurate to estimate the probability that the household is in negative equity. Following Deng et al. (2000) the standard error (se) estimates reported by OFHEO, which are derived from the repeat sales house price index estimation procedure and the cumulative normal density function (Φ), can be used to calculate the probability that the house has more debt than value-the probability of negative equity $(pneq_{jt})$. The standard error estimates depend on how long ago the home was purchased. Let s index the current date and t the date of the transaction so that $s - t$ is the time since the transaction. In general the larger $s - t$ the higher the estimated standard error from the house price index estimation procedure. Therefore, $pneq_{jt}$ is sensitive to changes in house prices, mortgage payments, and the standard errors.

$$pneq_{jt} = \Phi\left(ltvc_{jt}/se_{s-t}\right). \quad (8)$$

To indicate the level of credit impairment the Fair Isaac FICO score measured at origination is included for the borrower of each loan. It is expected that borrowers with very poor credit histories, and hence poor credit scores, will have a difficult time finding refinance options and may have more difficulty identifying whether the call option is in the money. In addition, borrowers who have poor credit scores but still have managed to obtain a prime loan are likely to have either implicitly or explicitly subsidized interest rates; they will then only find refinancing attractive when interest rates have dropped dramatically. From the default perspective borrowers with poor credit scores are more likely to continue poor credit management and default on a mortgage.

The ability of a borrower to continue making the mortgage payments in large part depends on being employed. This study uses monthly metropolitan level unemployment rates as a proxy. It is expected that borrowers in locations with higher unemployment rates are more likely to experience negative trigger events and are therefore more likely to have trouble making payments on time. One possible outcome besides defaulting on the mortgage is for the borrower and lender to work out a new payment plan, which may include prepaying the current mortgage. Another alternative is that borrowers who lose their jobs will not be able to refinance due to job status.

6. Results

Table 2 presents the results for prime loans and Table 3 for nonprime loans. Coefficient estimates, t-statistics, and the log of likelihood are reported as estimated by maximizing the likelihood function. For each loan type four specifications are provided-with and without unobserved heterogeneity and with and without credit scores (FICO). Due to unobserved variables and the importance of credit history in the underwriting process the preferred specification for both prime and nonprime loans includes both unobserved heterogeneity parameters and the FICO score.

One of the most striking results is the importance of credit scores. Higher credit scores are associated with elevated levels of prepayment and lower levels of defaults. The conditional probability of borrower *j* prepaying the mortgage in period t is modeled by

$$\pi\left(T_w = t | x_{jt}, \theta_w, T > t-1\right) = 1 - \exp\left(-\exp\left(x_{jt}\beta_w\right)\theta_w\right), \quad (9)$$

where x_{jt} represents the matrix of regressors, θ_w is the location parameters which represent the unobserved component of the likelihood function, and β is a vector of parameters measuring the effects of the x_{jt} on the probability (π) of w (w = default, prepay, or continue) occurring.

Using this expression the conditional monthly probability of defaulting on or prepaying a mortgage can be calculated. To clarify the effect of credit scores on the rate of prepayment and defaults Figures 1 and 2 present simulated probabilities over the full range of credit scores for both nonprime and prime mortgages. In all figures, the age of the loans is set to the 28th month of the mortgage and all other variables are set to their mean values except the variable of interest.[5] Figure 1 shows that as credit scores increase, or improve, default rates drop very quickly for both prime and nonprime mortgages. In addition, the figure indicates that prime mortgages default at a much lower level than nonprime mortgages for almost all credit scores. From the prepayment perspective the role of credit scores is the opposite. For both prime and nonprime mortgages higher credit scores indicate higher prepayment levels. However, nonprime mortgages are more sensitive to credit scores than prime mortgages. In general, when credit scores are low prime loans prepay more often, but when credit scores are of high quality, above 700, nonprime loans prepay more often.[6]

6.1. Prepayment Issues

The data presented in Table 1 show that prime loans prepay less often on average than nonprime loans. The cause of this elevated rate of prepayment cannot be determined definitively in this paper, but there are a number of plausible explanations: (i) Nonprime borrowers refinance because their credit history is improving as the loan is being paid off; (ii) Nonprime borrowers are more likely to refinance in order to take cash out of the house (cash out refinance); (iii) Nonprime borrowers are more sensitive to changes in interest rates; and (iv) Nonprime borrowers regret getting a high cost loan and actively pursue opportunities to lower their mortgage costs.

UBS Warburg (2002) found that nonprime loans prepaid at an elevated rate and interpreted it as evidence that borrower credit history was improving, which allowed them to refinance into a cheaper mortgage type. This type of refinancing can be labeled “credit-curing” refinancing, because it is predicated on the ability of a borrower with poor credit history to improve it while paying off the mortgage. In addition though, loans that survive to the next time period have by definition not defaulted. Therefore, it is likely the average credit history of a surviving nonprime loan is better than the credit history of the average loan at origination. In effect, by not defaulting the actual or contemporaneous credit riskiness of the loan is revealed as the loan ages. If credit quality improves because the highest risk loans default the fastest, then prepayment rates should continue to increase over a longer period of time for nonprime loans than prime loans because prime loans will not experience improving credit quality over

time on average.[7] The baseline parameters (age and age^2) show that for nonprime loans the prepayment rate is always increasing across all observed time (up to the 56th month) and peaks for prime loans at the 43rd month. Therefore, there is some indirect support for the credit-curing hypothesis at the aggregate or pool level.

Another possible explanation for the elevated prepayment rates is that they are being caused by the need to take cash out of the house (cash out refinances). If this hypothesis is true, then nonprime prepayment rates should be positively correlated to indicators of declining economic conditions. However, the econometric results presented in Tables 2 and 3 indicate that nonprime mortgages prepay less often as the unemployment rate increases. Therefore, there is no evidence supporting cash out refinances as the cause of the elevated prepayment rates.

In addition, nonprime mortgages may be more sensitive to changes in interest rates than prime borrowers. But, the coefficients presented in Tables 2 and 3 for the variable refi show that the responsiveness of prime mortgages is larger than the responsiveness of nonprime mortgages. In fact, the average nonprime mortgage prepays when it is not in the money to refinance $(refi < 0)$. This is illustrated in Figures 3 and 4, which show the probabilities of prepaying for a variety of refi values. Each figure has three lines. The top line and the bottom line reflect the estimated unobserved groups. The lines show that for prepayment there exists a group of borrowers who are not responsive to almost any change in interest rates-they very rarely prepay even when the financial incentives are quite large. In contrast, there exists another group of borrowers who are very responsive to changes in interest rates. Neither of these groups can be identified before the estimation, and they are therefore estimated as unobserved heterogeneity factors (location1 and location2). The mass points estimate the fraction of borrowers in each group. Mass point 1 is normalized to one and mass point 2 is estimated as any positive number. For instance, for prime borrowers the mass point 2 estimate of 1.002 indicates just over 50 percent of prime borrowers are in group 1 (the high level termination group) and just under 50 percent are in group 2 (the low level termination group). In contrast, for nonprime loans approximately 61 percent of the loans are in group 1, the group with the higher likelihood of prepaying. Figure 5 graphs the total or average prepayment rates for prime and nonprime mortgages for a variety of $refi$ values. It shows that when the option to refinance is out of the money $(refi < 0)$ nonprime borrowers refinance more than prime borrowers. In contrast, when the mortgage is deeply in the money $(refi > 7.6 \text{ percent})$ then a prime mortgage is more likely to prepay than a nonprime mortgage.

This paper finds some limited support for the hypothesis of credit-curing refinance activity at the pool or aggregate level, but no support for the cash out refinance or interest rate sensitivity hypothesis. In addition, this paper cannot reject the hypothesis that nonprime borrowers regret getting the high cost loan and actively pursue opportunities to lower their mortgage costs. This regret or buyer's remorse may lead to interactions with credit counseling and home ownership education organizations that may provide low cost and subsidized mortgages.[8]

6.2. Default Issues

As indicated above, one of the prime drivers of default rates is the credit score of the borrower at origination. Another factor that should affect default rates is the probability that the mortgage is in negative equity $(pneq)$. As expected, as the equity in the home decreases (or $pneq$ increases) the probability of default increases. Figure 6 provides a graph of this result for prime and nonprime mortgages. While both prime and nonprime are responsive to $pneq,$ the default rates are always substantially higher for nonprime loans. In addition, as the unemployment rate increases the default rate also increases for both nonprime and prime loans. While it may have made some sense to expect that nonprime mortgages would be more responsive to labor market conditions, this paper indicates that prime and nonprime loans are equally affected by different unemployment rates. The inclusion of $refi$ in the default equation indicates that as it becomes more in the money to refinance, the probability of defaulting is higher.

6.3. Comparisons of Prime and Nonprime Mortgage Results

To aid in the comparison of prime and nonprime mortgages Table 4 presents results when prime and nonprime borrowers are made to have exactly the same characteristics-those of the average prime borrower in the 28th month of the loan. Using the nonprime and prime model estimates, the probability of prepaying or defaulting is simulated for a variety of $fico_j,$ $pneq_{jt},$ and $refi_{jt}$ values. The ratio of the nonprime to prime probabilities is then calculated $(\pi^{\text{nonprime}}/\pi^{\text{prime}})$ and compared. Any number greater then one indicates that the probability is higher for nonprime than prime after making all of the characteristics the same.

Note the lack of uniformity in the results-sometimes the nonprime probability is higher, at other times the prime probability is higher. In general, the table shows that when credit scores are high and the option to refinance is out of the money, nonprime mortgages are up to 3.35

times more likely than prime mortgages to prepay. But as credit scores deteriorate or as the option to refinance becomes more in the money, nonprime mortgages are up to 42 percent less likely to prepay than prime mortgages. Therefore, while nonprime mortgages may prepay more often than prime on average, nonprime mortgages tend to prepay much less often than prime borrowers when low credit score loans experience a considerable drop in interest rates. Note that the differences are largest when $refi_{jt} = 0\%$. This is where a discontinuous step has been introduced into the $refi_{jt}$, because if a loan is out of the money it should not refinance due to interest rates, regardless of how much or how little it is out of the money. The step taken by prime loans is much larger than the step taken by nonprime loans, as can be seen in Figure 5 at $refi_{jt} = 0$.

Table 4(b) reports the same style of simulated probability ratios for default rates. For instance, nonprime mortgages default at least 1.87 times more often than prime mortgages (low credit scores and high $pneq_{jt}$). This difference is larger when credit scores are higher and the probability of negative equity is lower. At the most extreme, nonprime loans default approximately 7.69 times more often.

An interesting policy question is whether borrowers who should be in the prime market are in the subprime market or additionally are there many borrowers who should be in the subprime market that should be in the prime market? The results strongly indicate that the pricing (although only roughly measured by the contract rate on the mortgage) of the mortgages is related to mortgage performance-loans with higher interest rates prepay and default much more. Given the elevate rate of default the prepayment issue is especially important because lenders need to have loans that last a long time to compensate for the high default rate in order to maintain earnings. The nonprime loans in this paper do not have this compensating attribute. As a result, the cost to the borrower must be higher. This contrasts with low income/minority loans, which also typically have higher rates of default, but prepayment rates are lower (Van Order and Zorn, 2002; Deng and Gabriel, 2002). Given these results, there are still prime loans with very low credit scores or low down payments and nonprime loans with high credit scores and large down payments in the estimation data set. But, as shown in Table 4 the identical looking nonprime loan defaults at least 1.87 times more often than the identical looking prime loan even if both have credit scores of 500. This difference increases as the equity position and credit score of the household improves.

But, the evidence is not as compelling from the prepayment perspective. Table 4 shows that nonprime loans prepay much more often (up to 2.65 times more often) than the identical prime loan when it is out of the money to refinance and when the borrower has a high credit

score. Credit curing is not a relevant hypothesis to explain this finding since the credit score is high already. In addition, approximately 13 percent of the nonprime loans in the estimation data set have FICO scores above 750. While one potential explanation for the elevated prepayment rates is that the borrowers realized after the fact that they could qualify for a cheaper mortgage, these loans may be low documentation loans and the results may only indicate that low documentation loans prepay more often than other types of subprime loans.

Therefore, while it is beyond the ability of the paper to definitively state what fraction of the loans paying high interest rates should have qualified for prime rates, it does indicate that higher rates, at least on average, can be justified due to the elevated rates of default and prepayment.

6.4. Loss and Termination Comparisons

While the patterns of prepayment and default may be of interest in themselves, investors often separate the value, or risks, of the mortgage into credit and prepayment risks. Holders of the credit risk are concerned with events that will not return the full principal back to them, which is typically associated with defaulted loans. Holders of the prepayment risk are concerned with the cash flow or income stream from a mortgage, which is primarily impacted by prepayment rates.

When a loan defaults the cash flow is terminated and, typically, not all of the remaining balance is returned to the investor. In other words, the remaining or outstanding balance of the loan may not be fully recouped when the value of the home net of legal, holding, and selling costs is smaller than the remaining balance on the mortgage.[9] Lekkas et al. (1993) conducted a study on defaulted Freddie Mac loans. They found that defaulted loans with LTVs at origination between 80 and 90 percent lost on average 15 percent of the outstanding balance. This figure is used in this analysis to roughly approximate the losses associated with defaulted loans. Note that this is a very rough estimate because it does not include any risk sharing arrangements (mortgage insurance, for example), nor does it include the costs incurred when disposing of the property.

Investors who hold the prepayment risk are concerned with the rate at which loans terminate, regardless of whether the loan terminates because of prepayment or default. Tables 2 and 3 show that locations with higher unemployment rates, can simultaneously lead to higher default rates and lower prepayment rates. Therefore, in many cases the risks of default and prepayment counteract each other when estimating termination rates, so that termination rates can only be determined when the magnitude of both effects are quantified.

To quantify these effects for a variety of economic conditions Table 5 presents discounted cumulative credit losses and cumulative termination rates for the first three years of a $100 mortgage. The short time frame is used because it is the longest time frame that is strongly supported by the database used in this study. This increases confidence in the baseline probabilities used to create the cash flow estimates. All losses are discounted by the Fannie Mae constant maturity debt index.[10]

As expected for both prime and nonprime mortgages, increases in economic risk associated with decreases in house prices or high unemployment rates lead to higher credit losses. In addition, loans to borrowers with low credit scores also experience much higher expected credit losses.[11]

In contrast, when economic conditions are weak termination rates actually decrease. For instance, when the unemployment rate is increased from 3 to 10 percent the termination rate for prime loans decreases from 44.4 to 27.3 percent. Similar results occur for nonprime loans. This potentially counterintuitive result is largely caused by two related factors. First, as noted above, worse economic conditions move defaults and prepayments in opposite directions. Second, the number of prepayments is much greater than the number of defaults. Prepayments occur 37 times more than defaults for nonprime loans and 344 times more for prime loans in the data. Therefore, any factor that decreases prepayments (and thereby reduces termination rates) will swamp the increase in terminations due to default. This effect is stronger for prime loans and leads to higher termination rates for prime loans than for nonprime loans in high risk locations and time periods. This is because prepayments are even more constrained for nonprime borrowers in when housing and labor markets are performing poorly.

Lastly, the difference between termination rates of prime and nonprime loans is largest when it is out of the money to refinance (nonprime loans have a 13.8 percentage point higher termination rate) but is almost reduced to nothing when interest rates have dropped substantially, making it deeply in the money to refinance.

7. Conclusion

This paper provides a competing risk analysis, while incorporating individual loan unobserved heterogeneity, of the patterns of prepayment and default for prime and nonprime borrowers. Results indicate that nonprime borrowers do not have the same risk characteristics at origination, default and prepay at elevated levels, and respond differently to the incentives to prepay and default.

The findings of this paper confirm many preconceptions about nonprime borrowers, but defy others. Nonprime borrowers do prepay more quickly and default more often than prime borrowers, but this does not always hold true. For instance, when interest rates drop substantially prime borrowers refinance at a higher rate than nonprime borrowers. In addition, for low credit scores nonprime prepayments are depressed even further. While both prime and nonprime borrowers respond in the same direction (positive or negative) to economic stimuli (house prices, interest rates, or unemployment) and other indictors of risk (credit history and down payments), the magnitude of the responses can vary substantially.

An analysis of expected termination rates over a three-year time horizon shows that prepayment factors dominate default factors. For instance, loans tend to terminate less often when there are adverse economic conditions, because such conditions depress prepayments more than they increase defaults. Since nonprime loans are even more sensitive to this phenomenon, cumulative termination rates are higher for prime loans than nonprime loans in severe economic environments.

Notes

*. The views expressed in this research are those of the author's and do not represent policies or positions of the Office of Federal Housing Enterprise Oversight or other officers, agencies, or instrumentalities of the United States Government.

1. It is important to note that while private companies provide free of charge general characterizations of their results they do not provide actual estimates, econometric results, or the methodology used to estimate them. These details are presumably available to companies that use their services.

2. There is no information in the data set on the points paid by the borrower to buy down the interest rate. It is possible that borrowers who are paying higher rates are only doing so because they have not paid points or other origination fees. Therefore, it is possible to argue that any differences in prepayment rates could be partially attributable to interest rate buy downs, not alternative risk characteristics. The 100 basis point spread requirement should mitigate this potential problem. In fact, it is also likely that the standard interest rate group of borrowers will include high risk borrowers who have received explicitly subsidized interest rates or have qualified for special lending programs designed to increase lending to low income or minority households. If some prime loans are misclassified as nonprime and/or some nonprime loans are misclassified as prime loans this will make the

two loan classifications more similar, which would lead to more similar coefficient estimate (bias toward equality).

3. The author would like to thank Brian McCall for providing a copy of the Fortran code he developed to conduct the estimation.

4. The likelihood function is more general and allows *N* groups to be estimated. Attempts to estimate three or more groups did not converge because mass point estimates approached zero for at least one group. This provides support for the existence of only two distinct groups in this data set.

5. The age of the loan is set to the 28th month because it is approximately the middle of the observed time period for the loans and allows enough time for the typical ramping up of default and prepayment rates to occur.

6. Note that it is possible for nonprime loans to have borrowers with high credit scores, due to other deficiencies in the application such as not documenting income or down payment sources.

7. At some point the remaining loans in a typical pool will contain a large number of borrowers who will not refinance regardless of the changes in interest rates (the burnout effect) and prepayment rates should drop. In addition, as loans age it should become more difficult to recoup any transactions costs.

8. For an example, see the Chattanooga Neighborhood Enterprise (www.cneinc.org). They provide heavily subsidized mortgages to targeted areas in the Chattanooga, Tennessee region.

9. When the equity in the home is greater than the remaining balance of the loan, it is possible for gains to be made on defaulted loans after the property has been sold.

10. The debt index is reported by term structure and this term structure is incorporated into the monthly discounting term. Therefore, if d_t is the discounting term it varies over time.

11. Note that these results assume that the loss rate relates only to the initial LTV of the loan. Presumably, loss rates will increase in adverse economic environments, because current LTVs will deteriorate.

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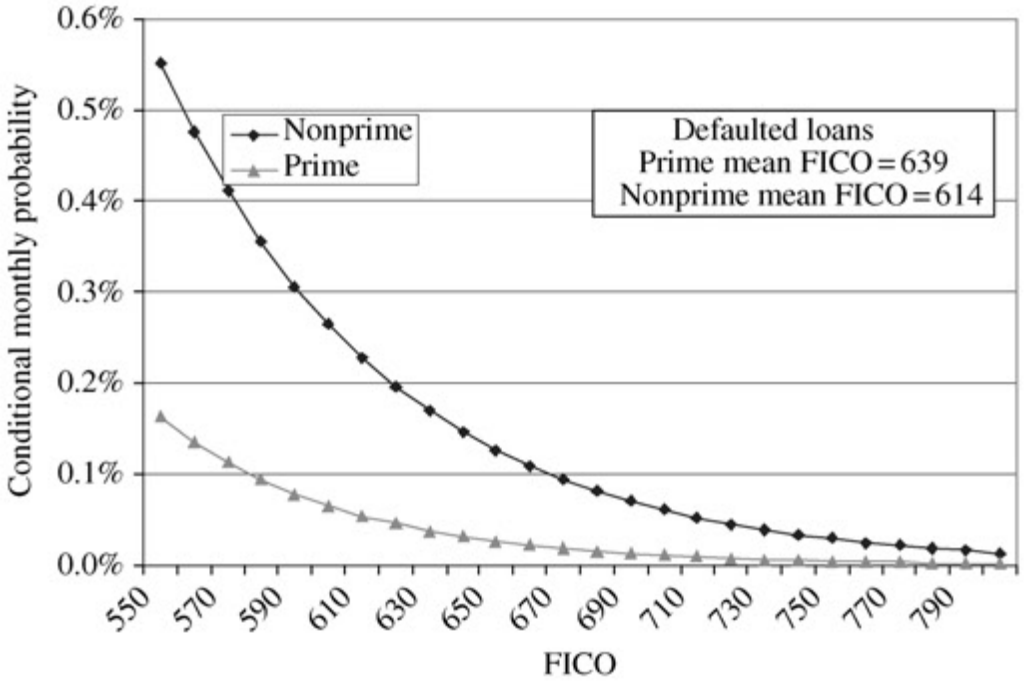
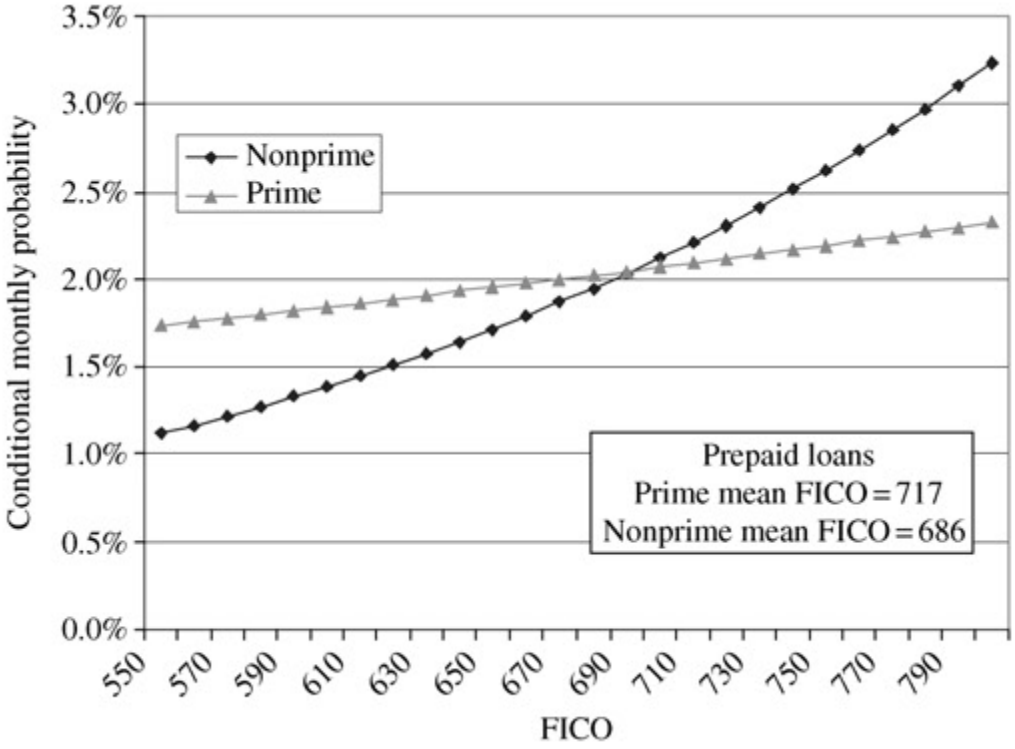
Appendix

Figure 1: Nonprime and Prime Default Sensitivity to FICO Score



The figures are evaluated in the 28th month of a typical loans life.

Figure 2: Nonprime and Prime Prepay Sensitivity to FICO Score



The figures are evaluated in the 28th month of a typical loans life.

Figure 3: Prime Prepay Sensitivity to Refinance in the Money

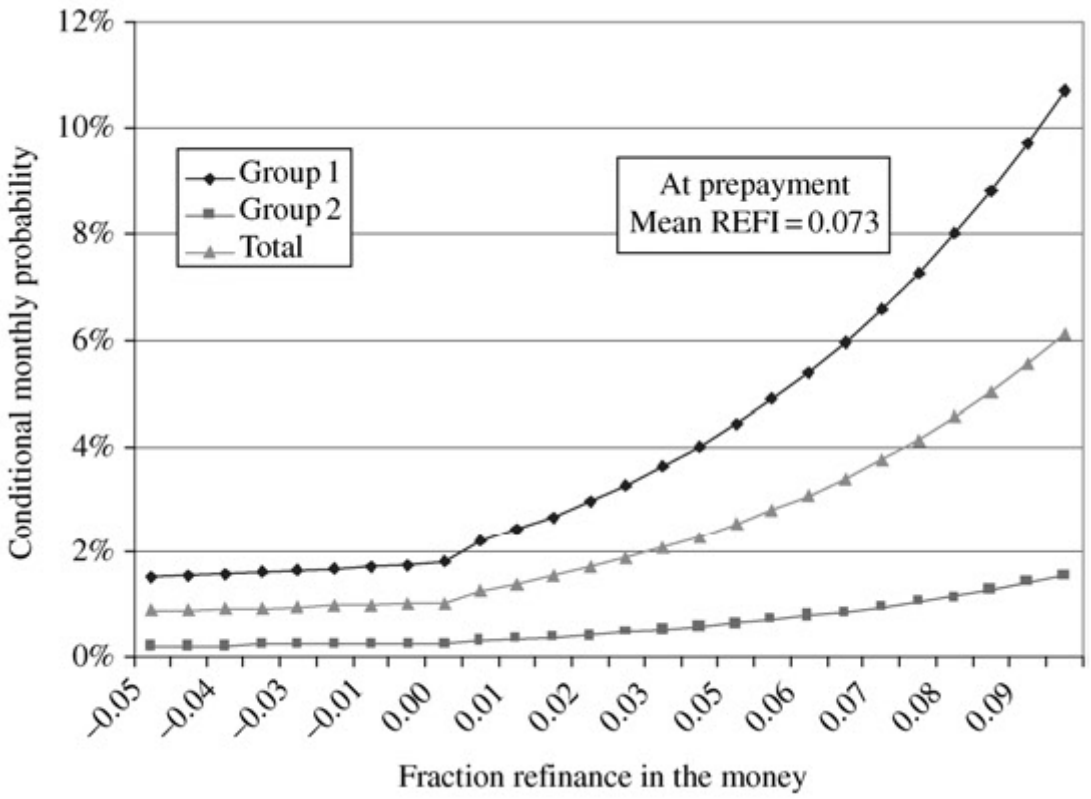


Figure 4: Nonprime Prepay Sensitivity to Refinance in the Money

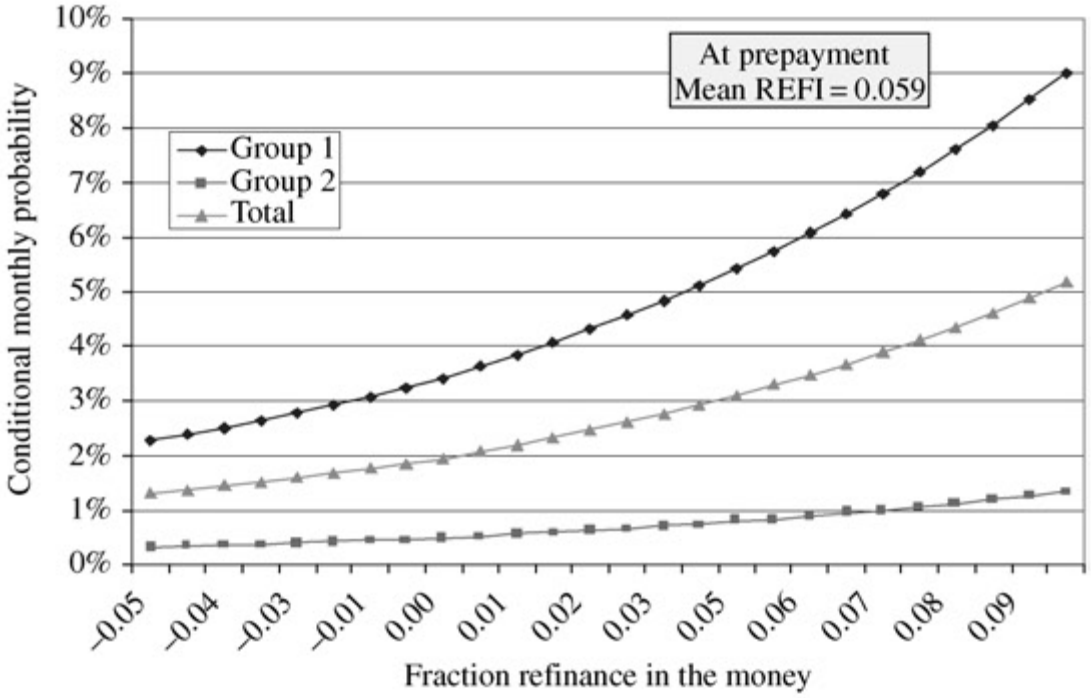


Figure 5: Nonprime and Prime Prepay Sensitivity to Refinance in the Money

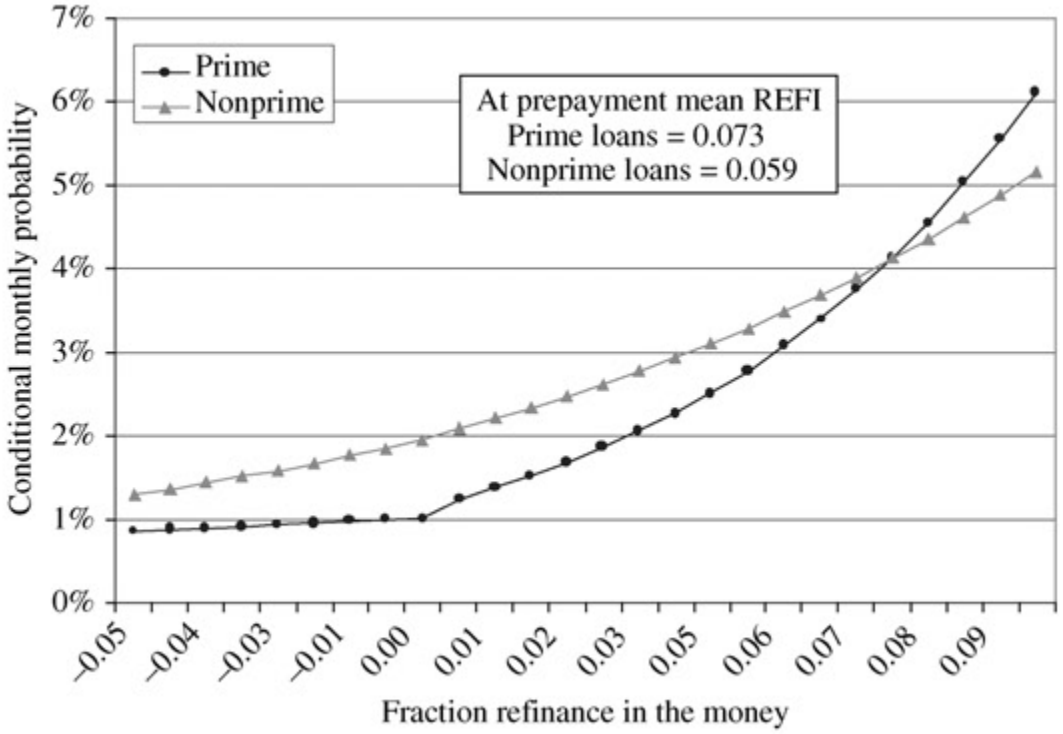


Figure 6: Nonprime and Prime Default Sensitivity to Probability of Negative Equity

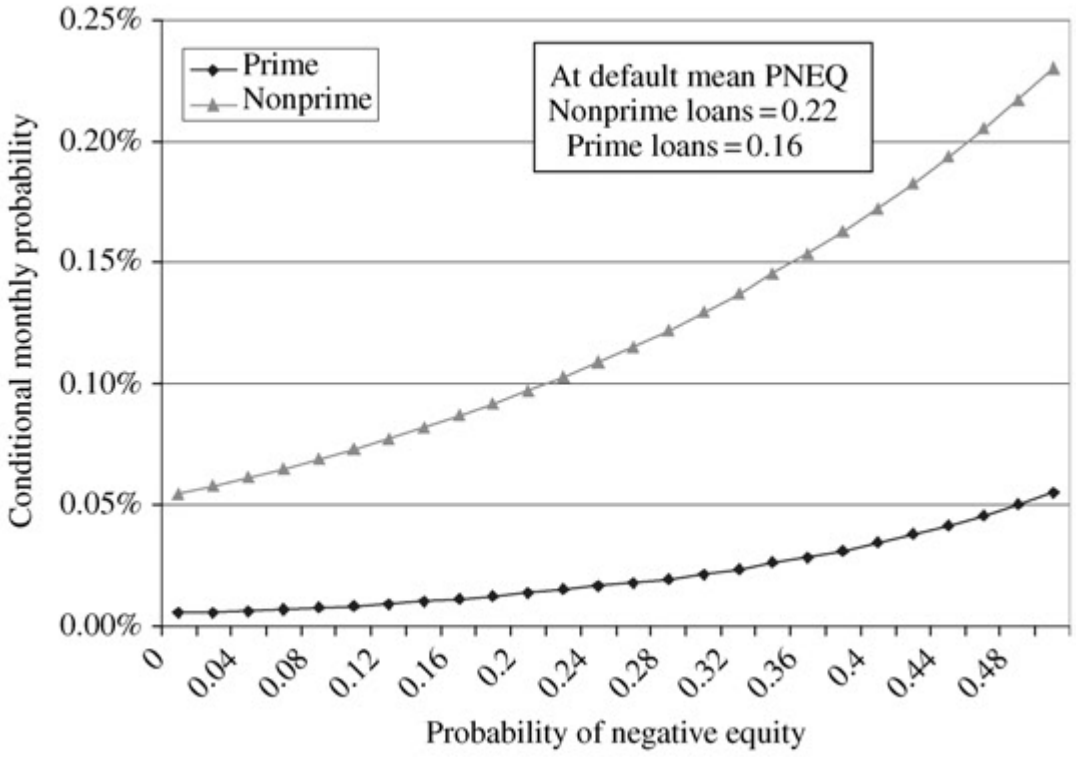


Table 1: Descriptive Statistics of Mortgage Mean Values at Origination and Termination

	At First Month				At Termination							
	All Loans				Defaulted Loans				Prepaid Loans			
	Prime Mean	Std Dev.	Nonprime Mean	Std Dev.	Prime Mean	Std Dev.	Nonprime Mean	Std Dev.	Prime Mean	Std Dev.	Nonprime Mean	Std Dev.
pneq	0.006	0.021	0.014	0.032	0.162	0.112	0.217	0.105	0.100	0.111	0.166	0.118
refi	0.008	0.033	0.009	0.035	0.044	0.054	0.036	0.061	0.073	0.047	0.059	0.050
urate	4.626	1.899	5.132	1.993	5.187	2.350	5.032	1.948	3.897	1.663	4.286	1.787
age	1.000	0.000	1.000	0.000	15.892	11.428	19.332	12.220	22.149	10.511	22.056	12.079
At Origination												
FICO	715.397	54.347	678.021	61.628	638.632	66.946	614.460	62.936	716.828	52.758	686.373	59.341
Loan to value ratio	0.821	0.144	0.888	0.116	0.911	0.082	0.931	0.058	0.821	0.142	0.884	0.116
Loan amount	112,955	44,707	98,650	47,608	109,765	46,731	93,800	45,434	119,161	44,779	108,240	47,304
Interest rate	7.953	0.500	8.944	0.437	8.240	0.634	9.088	0.513	8.121	0.477	9.006	0.443
Number of observations	24,018		65,992		185		3,062		10,860		38,289	

Table 2: Prime Results

	Without Unobserved Heterogeneity				With Unobserved Heterogeneity			
	Without FICO		With FICO		Without FICO		With FICO	
Variable	Coeff	*T*-stat	Coeff	*T*-stat	Coeff	*T*-stat	Coeff	*T*-stat
Default								
FICO			−1.806	−15.86			−1.827	−15.17
pneq	0.695	8.86	0.447	5.53	0.703	8.88	0.468	5.68
refi	0.030	1.47	0.018	0.90	0.044	1.93	0.033	1.53
refi ∗ (*refi* < 0)	0.017	0.30	0.038	0.66	0.000	−0.01	0.020	0.35
urate	0.116	3.91	0.108	3.82	0.110	3.60	0.102	3.52
age	−0.102	−4.35	−0.080	−3.38	−0.105	−4.27	−0.085	−3.47
age2	0.148	2.81	0.111	2.11	0.177	2.72	0.145	2.34
location1	0.00028	5.09	0.00016	4.90	0.00046	3.33	0.00027	3.91
location2					0.00010	1.02	0.00005	1.17
Prepay								
FICO			0.090	4.92			0.118	4.84
pneq	−0.052	−6.02	−0.039	−4.28	−0.070	−6.04	−0.053	−4.41
refi	0.137	55.65	0.138	55.77	0.170	53.34	0.170	53.46
refi ∗ (*refi* < 0)	−0.080	−7.77	−0.081	−7.83	−0.133	−12.27	−0.133	−12.36
urate	−0.080	−13.77	−0.079	−13.61	−0.091	−13.28	−0.090	−13.14
age	0.083	22.53	0.082	22.36	0.081	18.77	0.080	18.58
age2	−0.136	−18.51	−0.136	−18.41	−0.095	−10.41	−0.093	−10.22
location1	0.00355	24.66	0.00353	24.62	0.00580	20.54	0.00575	20.71
location2					0.00040	7.22	0.00038	7.27
Support points								
mass point 1	1.000		1.000		1.000		1.000	
mass point 2					1.006	9.66	1.002	9.88
Log of likelihood	−54,328.5		−54,204.2		−54,213.8		−54,086.2	

Notes. All variables except age and age^2 are mean deleted, where the means are calculated at the first observation for each loan. All variables are also scaled as follows—Fico/100, $pneq * 10$, $refi$ and $refi * (refi < 0) * 10$, age/1, and $age^2/100$.

Table 3: Nonprime Results

	Without Unobserved Heterogeneity				With Unobserved Heterogeneity			
	Without FICO		With FICO		Without FICO		With FICO	
Variable	Coeff	*T*-stat	Coeff	*T*-stat	Coeff	*T*-stat	Coeff	*T*-stat
Default								
FICO			−1.4761	−36.30			−1.4757	−35.51
pneq	0.4112	16.92	0.2880	10.99	0.4196	14.75	0.2879	10.86
refi	0.0212	3.25	0.0168	2.59	0.0172	2.21	0.0169	2.40
refi ∗ (*refi* < 0)	−0.0343	−2.16	−0.0209	−1.32	−0.0289	−1.73	−0.0210	−1.30
urate	0.0671	5.62	0.0699	6.82	0.0714	5.49	0.0698	6.64
age	−0.0183	−2.46	−0.0051	−0.68	−0.0201	−2.58	−0.0051	−0.68
age2	0.0269	1.80	0.0025	0.17	0.0218	1.40	0.0027	0.17
location1	0.0009	12.87	0.0006	12.34	0.0007	2.88	0.0006	5.80
location2					0.0012	3.85	0.0006	4.42
Prepay								
FICO			0.3155	25.96			0.4310	24.29
pneq	−0.1282	−20.12	−0.0901	−13.86	−0.1921	−19.97	−0.1404	−15.51
refi	0.0735	39.70	0.0749	40.46	0.0980	41.54	0.0974	41.75
refi ∗ (*refi* < 0)	0.0277	4.33	0.0250	3.91	−0.0126	−1.84	−0.0124	−1.82
urate	−0.0980	−23.62	−0.0976	−23.64	−0.1158	−23.30	−0.1144	−23.40
age	0.0699	29.71	0.0670	28.46	0.0697	24.11	0.0660	23.38
age2	−0.1077	−23.27	−0.1031	−22.26	−0.0642	−9.61	−0.0587	−9.17
location1	0.0089	40.68	0.0085	40.28	0.0141	31.66	0.0128	33.47
location2					0.0020	12.99	0.0018	13.63
Support points								
mass point 1	1.0000		1.0000		1.0000		1.0000	
mass point 2					0.7228	12.26	0.6334	13.11
Log of likelihood	−100,090.4		−99,149.4		−99,961.5		−98,993.5	

Notes. All variables except age and age^2 are mean deleted, where the means are calculated at the first observation for each loan. All variables are also scaled as follows—Fico/100, $pneq * 10$, $refi$ and $refi * (refi < 0) * 10$, age/1, and $age^2/100$.

Table 4: Probability Ratios $(\pi^{\text{Nonprime}}/\pi^{\text{Prime}})$ for Identical Observed Borrower and Loan Characteristics

(a) Conditional monthly prepayment rate

		Credit Score ($fico_j$)			
Age of Loan	$refi_{jt}$	500	600	700	800
26th month	− 5%	1.05	1.43	1.95	2.65
	0%	1.33	1.82	2.47	3.35
	5%	0.82	1.11	1.51	2.04
	10%	0.58	0.78	1.06	1.42

(b) Conditional monthly default rate

		Credit Score ($fico_j$)			
Age of Loan	$pneq_{jt}$	500	600	700	800
26th month	0%	2.68	3.81	5.41	7.69
	5%	2.44	3.48	4.95	7.03
	10%	2.23	3.18	4.52	6.43
	20%	1.87	2.66	3.78	5.37

Notes. Prime and nonprime borrowers have identical characteristics in this table. If the ratio equals one then the probability is equal for prime and nonprime borrowers. If the ratio is greater (less) than one then nonprime borrowers have a higher (lower) probability. For instance, a ratio of 1.1 indicates that nonprime borrowers have a 10 percent higher probability; and a ratio of 0.4 indicated that nonprime borrowers have a 60 percent lower probability. This statistic is also referred to as an odds ratio. *j* indexes the individual loans and *t* indexes time in months.

Table 5: Losses and Termination Comparisons

Description	Mortgage Type	Cumulative Credit Losses	Cumulative Termination Rate (%)	Outstanding Balance
High house price growth—$pneq = 1\%$	Prime	0.04	42.3	$57.72
	Nonprime	0.25	45.9	$54.14
Low house price growth—$pneq = 20\%$	Prime	0.10	39.5	$60.54
	Nonprime	0.46	38.8	$61.21
Low unemployment—$urate = 3\%$	Prime	0.05	44.4	$55.58
	Nonprime	0.34	45.7	$54.25
High unemployment—$urate = 10\%$	Prime	0.11	27.3	$72.68
	Nonprime	0.61	26.6	$73.38
High interest rates, refinance ''out of the money''—$refi = -5\%$	Prime	0.04	19.2	$80.78
	Nonprime	0.42	33.9	$66.10
Low interest rates, refinance ''in the money''—$refi = 5\%$	Prime	0.06	49.1	$50.87
	Nonprime	0.39	62.9	$37.07
Lower interest rates, refinance ''in the money''—$refi = 10\%$	Prime	0.06	79.5	$20.45
	Nonprime	0.36	79.6	$20.40
Low credit score & low interest rates—FICO $= 500$ & $refi = 10\%$	Prime	2.79	77.7	$22.26
	Nonprime	4.84	72.0	$28.02

Notes. All results are generated for the first three years of the mortgage for a $100 loan. All variables, except the age of the loan, are held at their means unless specified differently in the scenario description. Losses on defaults are estimated from Lekkas, Quigley and Van Order (1993) page 360, which is based on Freddie Mac loss severity history. The cumulative termination rate and the outstanding balance are reported at the end of the three years. Credit losses are discounted by the Fannie Mae Constant Maturity Debt Index as reported by Haver Analytics Inc. on June 2002.