Effects of Regulation on Prepayment and Default of Subprime Mortgages

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Abstract

This study examines the effects of restrictions on prepayment penalties on prepayments and defaults of subprime mortgages from theoretical and empirical perspectives. The theoretical model suggests that, if lenders substitute points for prepayment penalties, prepayment rates will rise and default rates fall. Empirical results are consistent with predictions of the theoretical model. Controlling for other factors, estimated probabilities of prepayment were higher in the states that have restricted prepayment penalties. Though no definite conclusions could be drawn regarding the effect of state laws on subprime defaults, there is an evidence that early defaults decreased as regulation expanded.

Introduction

This study examines the effects of subprime credit market regulations[1] on termination of subprime mortgages. Specifically, it shows how state predatory lending legislation, which has been a model for recent changes in federal regulation[2], affects prepayments and defaults in the subprime market.[3] The theoretical model explains the effect of state predatory lending legislation by considering restrictions on prepayment penalties, a common feature of many laws. The model is based on the option-pricing structural approach to mortgage valuation, suggested by Kau, Keenan, Mueller, and Epperson (1992, 1995). Optimal mortgage termination conditions resulting from the theoretical model are then applied to specify two empirically testable hypotheses. First, it is shown that eliminating prepayment penalties from mortgage contract raises the value of prepayment option, and makes prepayment even more likely when housing prices increase and interest rates decline. Therefore, the *predatory lending laws are expected to result in higher prepayment rates in the subprime market.* Second, eliminating prepayment penalties from the mortgage contract lowers the value of the default option, and makes default less likely to occur when housing prices decline. Therefore, the *predatory lending laws are expected to result in lower default rates in the subprime market.*

These hypotheses are tested by estimating competing risks models of mortgage termination to predict probabilities of prepayment and default on 30-year fixed-rate subprime mortgage data. The estimation procedure is based on the competing risks proportional hazards approach suggested by Deng, Quigley, and Van Order (2000) but includes penalized splines smoothing that allows the covariate effects to vary functionally with time. These probabilities are then compared between regulated and unregulated states to evaluate the extent to which predatory lending laws affected prepayment and default decisions.

Prepayments and defaults of subprime mortgages were recently analyzed in a number of studies, of which

[1] The subprime mortgage market is regulated at both federal and state levels. In 1994, Congress enacted the Home Ownership and Equity Protection Act (HOEPA), which imposed additional Truth in Lending disclosures and certain restrictions on contract terms for high-cost mortgages. Since passage of HOEPA, many states, cities, and counties have enacted HOEPA-like "predatory" mortgage lending laws. These laws often have thresholds for defining high cost mortgages that are lower than HOEPA, impose more stringent restrictions on "high-cost" mortgages than "non-high-cost" mortgages, and sometimes impose restrictions on broader classes of mortgages.

[2] In July 2008 the U.S. FED Board of Governors amended HOEPA provisions, requesting lenders to verify a borrower's ability to repay a loan, setting more extensive minimal documentation requirements, and banning prepayment penalties on higher-priced loans.

[3] This study is concerned with the initial effects of subprime regulation rather than its final collapse. Sorting out the relative effect of subprime regulation as opposed to other events causing the collapse of yield spread premiums, the secondary market and substantial numbers of both subprime lenders and secondary market investors is beyond the scope of this analysis.

notable contributions are by Danis and Pennington-Cross (2005), Ho and Pennington-Cross (2006b), and Pennington-Cross (2006). However, this paper is the first, which explicitly relates credit market regulations to termination of subprime mortgages.

The main finding of this study is that controlling for other factors, the estimated probability of prepayment is found to be higher in the states that have introduced predatory lending laws. Although no definite conclusions can be drawn regarding the effect of state laws on subprime defaults, there is some evidence that early defaults have decreased as the scope of regulation expanded. These results suggest that, as anticipated by the theoretical model, predatory lending laws lowered defaults and raised prepayments in the subprime market.

1 Literature Review

The contingent claims model developed by Black and Scholes (1973), Merton (1973), and others provides a coherent theoretical framework for analyzing borrower behavior. A number of studies applied this model to the mortgage market.[4] Pricing of mortgage contracts is complicated, because the borrower has options to prepay or default. These options are distinct but not independent. For example, a borrower whose property price declines below the mortgage balance may not default immediately, in part because the borrower would lose the options to refinance or default later.[5] That is, one cannot calculate accurately the economic value of the default option without considering simultaneously the final incentive for prepayment. A series of papers by Kau, Keenan, Muller, and Epperson[6] provided theoretical models that emphasized the importance of the interdependence of prepayment and default options. Ambrose, Buttimer, and Capone (1997) made further improvement in modeling prepayment and default options, by explicitly introducing into the option-pricing framework the delay of foreclosure and the concept that the decision to stop making payments is determined by expected values of the property well into the future (at the foreclosure date).

[4] For a summary of this line or research see Kau and Keenan (1995).

[5] Exercising these options later will make the borrower better-off if interest rates decline (which increases the value of prepayment option) or the property prices fall (which increases the value of default option) in the future. Immediate default may also not occur if interest rates increase, which rises the capital gain on the mortgage and offsets the effect of reduction in equity on the house. Another reason for not defaulting immediately is to avoid worsening of credit history. Defaulting and buying back the same house would require paying a higher interest rate or making larger downpayment.

[6] See Kau and Keenan (1995), and references therein.

There is an extensive literature providing empirical estimates of mortgage default and prepayment, which encompasses several approaches. The first approach applies the Cox proportional hazards model with competing risks and group duration data.[7] The second approach relies on multinomial logit models with restructured event history.[8] The third approach uses reduced-form mortgage valuation models to estimate default and prepayment processes.[9]

Empirical studies of prepayment and default in the subprime market have only recently begun to appear. None of these works has studied the effects of credit market regulations on termination of subprime mortgages.[10] However, some inferences can be drawn from their analysis of loan contract provisions, which may be subject to regulation. The main findings of these studies are as follows. Danis and Pennington-Cross (2005) found that subprime loans with prepayment penalties and limited documentation are associated with higher likelihood of delinquencies and defaults.[11] Quercia, Stegman, and Davis (2005) found that loans with prepayment penalties and balloon payment requirements have a significantly higher mortgage foreclosure risks, controlling for other risk factors, such as borrowers' credit history, loans' characteristics and purpose, housing type, and state-level macroeconomic fundamentals. Based on their findings Quercia, Stegman, and Davis (2005) argued for tighter restrictions on these loan contract terms.[12] Gerardi, Lehnert, Sherlund, and Willen (2008) found that risky contract provisions result in higher default risk but the risk becomes really high when housing prices decline. On the contrary, Mayer, Piskorski, and Tchistyi (2008) showed that less creditworthy borrowers are the most likely to choose prepayment penalties, and default at a lower rate than comparable borrowers with no prepayment penalties, and suggested that "regulations banning refinancing penalties might have the unintended consequence of raising interest rates, increasing mortgage default, and limiting available credit for the riskiest borrowers."[13]

Reconciling the results and policy recommendations of these studies is difficult because of the complex way, in which subprime loan terms and regulatory measures interact. For example, Rose (2008) found

[7] Deng, Quigley and Van Order (2000)

[8] Clapp, Goldberg, Harding and LaCour-Little (2001), Clapp, Deng, and An (2006)

[9] Kau, Keenan, and Smurov (2006)

[10] In a related work Pennington-Cross (2006) studied the effect of state foreclosure laws on the duration of subprime foreclosures.

[11] Based on the same data but different estimation method Ho and Pennington-Cross (2006b) also found that loans with lower documentation have a higher probability of default.

[12] Quercia, Stegman, and Davis (2005, p. 28).

[13] Mayer, Piskorski, and Tchistyi (2008, p.1)

that the effect of loan contract provisions, such as prepayment penalty, a balloon payment, or low- or no-documentation on the probability of foreclosure depends significantly on (a) the category of the loan under consideration, and (b) the presence or absence of the other two loan features. The relationships among the loan features and foreclosures are thus much more complex than previous analyses portray, limiting the ability of regulators and legislators to anticipate the effects of regulation on the cost and availability of subprime credit.[14]

2 Theoretical Model

The purpose of this theory section is to explore what can be said, a priori, from an option pricing perspective, about the expected effects of eliminating prepayment penalties in the subprime market, where they play such an important role given the attractiveness of refinancing to those whose credit history improves. The model adapts option-pricing structural approach to U.S. mortgage valuation and closely follows the works of Kau, Keenan, Mueller, and Epperson (1992, 1995).[15] This approach is natural, because it allows for analyzing borrower's decisions of prepayment and default in a complex setting, which involves stochastic housing prices and term structure of interest rates. Specifically, house price $H(t)$ is modeled as a log-normal diffusion process[16]:

$$dH = (\alpha - s)Hdt + \sigma_H H dX_H, \tag{1}$$

where α is the expected rate of house appreciation, s is the house's rate of rental or service flow, σ_H is house-price volatility, and X_H is a stochastic element of house price. The interest rate $r(t)$ is modelled as mean-reverting Cox-Ingersoll-Ross (CIR) process[17]:

$$dr = \gamma (\theta - r) dt + \sigma_r \sqrt{r} dX, \tag{2}$$

[14] Rose (2008, p.28).

[15] Other studies, which analyze prepayment penalties based on option-pricing approach to mortgage valuation are Fu, LaCour-Little, and Vandell (2003), and LaCour-Little (2007).

[16] See Merton (1973).

[17] See Cox, Ingersoll, and Ross (1985b).

where θ is the long-term value for the interest rate, γ is the speed of adjustment in the mean reverting process, σ_r is interest-rate volatility and X_r is a stochastic element of interest rate. Both stochastic elements X_H and X_r follow the standardized Wiener process, and are correlated according to

$$dX_H dX_r = \rho dt, \tag{3}$$

where ρ is the instantaneous correlation coefficient between the two Wiener processes. With the stochastic processes specified by (1) and (2), the partial differential equation (PDE) for valuation of assets is solely a function of the house price and interest rate and takes the form:

$$\begin{aligned} &\frac{1}{2}H^2\sigma_H^2\frac{\partial^2 X}{\partial H^2} + \rho H\sqrt{r}\sigma_H\sigma_r\frac{\partial^2 X}{\partial H \partial r} + \frac{1}{2}r^2\sigma_r^2\frac{\partial^2 X}{\partial r^2} + \\ &\gamma\left(\theta - r\right)\frac{\partial X}{\partial r} + \left(r - s\right)H\frac{\partial X}{\partial H} + \frac{\partial X}{\partial t} - rX = 0, \end{aligned} \tag{4}$$

where X is the value of the relevant asset.[18] The solution of equation (4) must include the value of the remaining payments to the lender, and the borrower's option to terminate the contract prior to maturity by either prepayment or default. These components of the mortgage - amortization schedule, and the financial determination of both prepayment and default, interact in a complex way, the value of one cannot be determined without consideration of the other.

The mortgage contract provisions are given as follows. For a fixed-rate mortgage the loan is repaid by a series of equal monthly payments on predetermined, equally spaced dates. The mortgage payment M and the unpaid principal after i^{th} month $U(i)$ are calculated as

$$M = \left[L * \frac{\left(c/12\right)\left(1 + c/12\right)^n}{(1 + c/12)^n - 1}\right], \text{ and} \tag{5}$$

$$U(i) = \left[L * \frac{\left(1 + c/12\right)^n - \left(1 + c/12\right)^i}{(1 + c/12)^n - 1}\right], \tag{6}$$

[18] The derivation of (4) follows from standard arguments in finance, see e.g. Cox, Ingersoll, and Ross (1985a, 1985b).

where L is the loan amount, c is the fixed yearly contract rate, and n is the term of the loan in months. If the decision to prepay the mortgage is made, the borrower is liable to prepay the lender an amount equal to the unpaid principal plus accrued interest between payment dates, and the penalty for early termination of contract (prepayment penalty). This amount is calculated as

$$F(t) = (1+\psi)\,(1+c\,(t-\tau\,(i)))*U\,(i)\,, \tag{7}$$

where $\tau(i)$ is the calendar time of the i^{th} month, t is the time that has elapsed between payment dates i and $i+1$, and ψ is the prepayment penalty.

The value of the mortgage contract $V\,(H,r,\tau(i))$ at period i is modeled as the difference between the value of remaining future payments promised to the lender $A\,(r,\tau(i))$, and the value of the borrower's options to prepay $C\,(H,r,\tau(i))$, eliminating debt early, and the option to default $D\,(H,r,\tau(i))$, turning over the value of collateral to the lender.[19] Formally, the value of the mortgage is given as

$$V\,(H,r,\tau(i)) = A\,(r,\tau(i)) - C\,(H,r,\tau(i)) - D\,(H,r,\tau(i)) \tag{8}$$

At each payment date between origination and termination of the mortgage, the borrower holds a position

$$H\,(\tau(i)) - V\,(\tau(i),i)\,, \text{where} \tag{9}$$

$$A\,(\tau(i),i) = A\,(\tau(i),i+1) + M, \tag{10}$$

$$V\,(\tau(i),i) = \min\left[V\tau(i+1) + M, H\,(\tau\,(i))\right], \tag{11}$$

$$C\,(\tau(i),i) = \begin{cases} C\,(\tau(i),i+1) \;\; if \;\; V\,(\tau(i),i) = V\tau(i+1)+M \\ 0 \; if \; V\,(\tau(i),i) = H\,(\tau\,(i)) \end{cases}, \text{ and} \tag{12}$$

$$D\,(\tau(i),i) = \begin{cases} D\,(\tau(i),i+1) \;\; if \;\; V\,(\tau(i),i) = V\tau(i+1)+M \\ A\,(\tau(i),i) - H\,(\tau\,(i)) \;\; if \;\; V\,(\tau(i),i) = H\,(\tau\,(i)) \end{cases}. \tag{13}$$

Valuation of the stream of promised future payments $A\,(r,\tau(i))$ is relatively straightforward, and involves only the term structure of the interest rates. Valuation of prepayment and default options $C\,(H,r,\tau(i))$ and $D\,(H,r,\tau(i))$ is more difficult. Default occurs when the value of the house is less than the sum of monthly

[19] Some option-theoretic models of mortgage valuation also consider the values of mortgage insurance and co-insurance. These assets are not considered here, because subprime loans are rarely insured.

payment plus the value of the mortgage immediately after the payment is made. Default is thus a purely financially motivated, and is rational only when payments are immediately due, because borrowers can extract utility from housing service flows before the payment is contractually required. Unlike default, prepayment may occur any time, because both interest rates and housing prices are changing continuously. The prepayment option is "in the money" when the market value of the mortgage is greater than the sum of unpaid principal, accrued interest between payment dates, and prepayment penalty:

$$V\left((\tau(i), i)\right) = F(t). \tag{14}$$

If equation (14) holds true, prepayment is "in the money", and it is financially optimal for the borrower to prepay the debt. Note that it follows from equation (12) that the value of prepayment option is zero when the value of the house is less than the sum of monthly payments plus the value of the mortgage immediately after the payment is made. This happens because prepayment and default options are mutually exclusive, e.g. if default occurs, prepayment cannot happen.

Finally, at the origination of contract it is assumed that neither the borrower nor the lender would enter into an agreement unless both parties agreed and the mortgage terms were determined based on current market conditions. That is the value of the contract at the time of origination (including any up-front points charged) be the same to the lender as the value of the loan to the borrower. Formally,

$$V\left(H\left(0\right), r\left(0\right), c\right) = \left(1 - \delta\right) L, \tag{15}$$

where δL is the value of the up-front points.

The mortgage is treated as a compound option, where the payoff to an option expiring at month's end is a further set of options covering the next month. Because current value of the mortgage is affected by potential future states, the problem should be solved backward in time, with the value of later options feeding into the earlier ones through the terminal conditions at the end of each month, which are given by equations (10)-(13).[20] This "full" problem does not have analytical closed-form solution.

[20] To solve the fundamental PDE (4) using recursive equations (10) - (13), one needs to know the equations describing the borrower's position at the time of maturity, and appropriate boundary conditions. These equation can be found in Kau, Keenan,

Model solution method adapted in this paper is based on singular perturbation approach suggested by Sharp, Newton, and Duck (2008). The key assumption for the application of this approach is that housing price and interest rate volatilities σ_H and σ_r are small numerically[21], as they multiply higher order derivatives in equation (4). Thus, setting these parameters to zero will not result in a significant bias in solution to equation (4)[22], which becomes

$$\gamma\left(\theta-r\right)\frac{\partial X}{\partial r}+\left(r-s\right)H\frac{\partial X}{\partial H}+\frac{\partial X}{\partial t}-rX=0. \tag{16}$$

Equation (16) is first-order, three dimensional PDE, which has closed-form solution, given by

$$X\left(H,r,\tau\left(i\right)\right)=X_0\left(H_0,r_0\right)\exp\left(\frac{1}{\gamma}\left(\theta-r\right)\left(1-e^{-\gamma\tau(i)}\right)-\theta\tau(i)\right), \text{where} \tag{17}$$

$$X\left(H,r,\tau\left(i\right)\right)=X_0\left(H_0,r_0\right) \tag{18}$$

is the general initial condition for month i, and H_0 and r_0 are the starting values of housing price and interest rate respectively given by

$$H_0=H\exp\left(\left(\theta-r\right)\tau(i)-\frac{1}{\gamma}\left(\theta-r\right)\left(1-e^{-\gamma\tau(i)}\right)\right), \text{and} \tag{19}$$

$$r_0=\theta-\left(\theta-r\right)\exp\left(-\gamma\tau(i)\right). \tag{20}$$

The model can now be solved by using equation (17) to find a general solution for assets A, V, C,and D in the final month of the problem, and iterating back by recursive substitution using equations (10)-(13) until the first month of contract is reached. Figures 1 - 4 (Appendix 1) illustrate the computed values of these assets at the origination of contracts with a prepayment penalty.

We can use a state-space diagram to illustrate the effect of credit market regulations on termination of subprime mortgages. Specifically, it is assumed that credit market regulations take form of restrictions on prepayment penalties, which is a common feature of the many state predatory lending laws. Prepayment penalties are far more common in the subprime market than in the in the prime market[23]. Because of risk-

Mueller, and Epperson (1995), pp.10-11, Appendix A, and Appendix B.

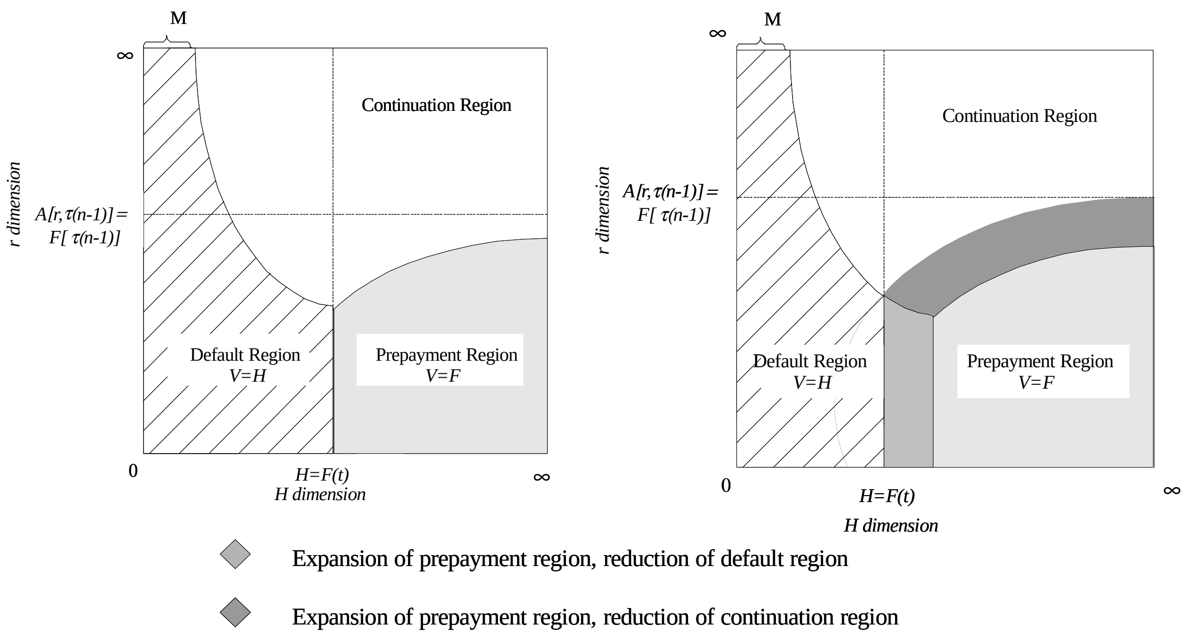
[21] Kau, Keenan, Mueller, and Epperson (1992, 1995) for example, set them equal to around 0.05 (per $(\text{annum})^{\frac{1}{2}}$).

[22] Sharp, Newton, and Duck (2008) prove this by comparing the results from "full" problem defined by the equation (4) and the results from "restricted" problem, and finding very little difference.

[23] Subprime loans are more than three times as likely as prime loans to have prepayment penalty terms in their mortgage contract, and the refinance lock-outs are usually in effect for two to five years. Prepayment penalties are usually binding for borrowers that have them (Cutts and van Order 2005).

based pricing, subprime borrowers who improve their credit score have the ability to refinance at a lower rate even if the yield curve remains constant. This causes higher rates of prepayment for subprime mortgages. Subprime lenders recognize that the best risks are most likely to refinance and the resulting adverse selection is a significant cost to them. Prepayment penalties are thus a reaction to the high level of prepayment risk associated with subprime mortgages.

Figure 1: State Space Dynamics of Unregulated and Regulated Mortgages on Monthly Payment Date.



This theoretical model is capable of illustrating the effects of restrictions on prepayment penalties on prepayment and default in subprime lending. Figure 1 does this by showing the dynamics of unregulated and regulated mortgages at the time $\tau(n)$ after origination, when the mortgage payment is due.[24] The left-hand side of the Figure 1 describes the dynamics of a loan, not subject to prepayment regulations. Depending on the value of the interest rates and house prices the loan can be located in one of three regions. The shaded area, which encompasses high housing prices and low interest rate, is prepayment region. This region is bound above by the value of interest rate at which $A[r, \tau(n-1)]$ is equal to $F[\tau(n-1)]$, because at higher interest rates prepayment ceases to be of positive value. As interest rates fall below this critical

[24]This is the most interesting case scenario, because it considers both prepayment and default options. At the time of mortgage origination, default is not optimal, because the borrower can always wait until the mortgage payment is due, and extract the flow of housing services. At the final payment date, prepayment never ocuurs, because the mortgage is paid in full.

value, prepayment is "in the money"[25], but it does not necessarily occur, because of the opportunity cost of lost future prepayment or default. Prepayment region is bounded to the left by the line $H = F(t)$, where prepayment is as attractive as default (in financial terms).

The dashed area, which comprises low housing prices and low interest rates is the default region. This region must be to the left of the line $H = F(t)$, because there immediate default can have positive value. The interior boundary between the default region and the continuation region (depicted by the white area) is negatively sloping, because higher interest rates lower the cost of continuing the loan, and thus make default financially worthwhile only at low house values. The default option is "in money" when the present value of future mortgage payments, $A[r, \tau(n-1)]$ is greater than the value of the house H. As with prepayment, being "in the money" is a necessary, and not a sufficient condition for default to occur.

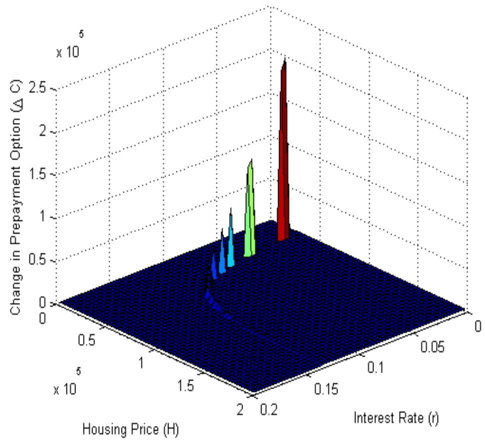
The right-hand side of the Figure 1 describes the dynamics of a loan, which is subject to prepayment regulations. Specifically, it is assumed that prepayment penalties are prohibited in the loan's contract. The analysis of such prepayment regulation is complicated by the fact that prepayment penalties enter the loan contract and affect the equilibrium rate at origination, which, in turn determines the values of future mortgage payments, prepayment, and default. To avoid this complication, the right-hand side of the Figure 1 considers the loan with prepayment penalty ψ replaced by higher points δ at origination, so the equilibrium contract rate at origination remains the same, and the arbitrage condition (15) is satisfied.[26] The effect of restricting prepayment penalties (e.g. setting $\psi = 0$) thus results in a lower value of total debt between payment dates in equation (7). In Figure 1 this effect is illustrated by the leftward shift in the $H = F(t)$ line, the upward shift in the $A[r, \tau(n-1)] = F[\tau(n-1)]$ line, and the expansion of the prepayment boundary (14). As a result of prepayment regulations, prepayment region expands, making prepayment option more likely, and the continuation and default regions contract, so the likelihoods of these events decline. Figure 2 illustrates the simulated results of a change in the value of the prepayment option at origination if a prepayment penalty of 1 percent is replaced by points, and the arbitrage condition is satisfied.[27]

[25] See Kau, Keenan, Mueller and Epperson (1995), p. 14

[26] One reason to expect that under regulation lenders will choose to trade prepayment penalties for points, and not change the contract rate is the adverse selection problem. Both points and prepayment penalties (but not the contract rates) help to achieve separating equilibrium and sort out between borrowers with different likelihoods of prepayment. For more details, see Brueckner (1994), LeRoy (1996), and Steinbuks (2008).

[27] The model's solution is based on the following values of economic environment and mortgage contract variables: $r(0) = 10\%$, $H(0) = \$100,000$, $c(0) = 10\%$, $\theta = 10\%$, $\gamma = 25\%$, $s = 8.5\%$, $\sigma_H = \sigma_r = \rho = 0$, $n = 60$, $\psi = 1\%$, and $\delta = 1$ point. The model

Figure 2: Simulated Effects of Prepayment Regulations on the Value of Prepayment Option.



Based on the theoretical results above we can formulate and subsequently test the following two hypotheses about the effects of credit market regulations on termination of subprime mortgages. First, eliminating prepayment penalties from mortgage contracts reduces the amount the borrower is liable to pay the lender if the prepayment option is exercised, raising the value of prepayment option, and making prepayment likely at smaller increase in housing prices or decline in interest rates. Therefore, the first hypothesis can be formulated as

Hypothesis 1: Predatory lending laws lead to higher prepayment rates in the subprime market.

Second, eliminating prepayment penalties from the mortgage contract reduces the value of borrower's total debt to be paid if decision to refinance is made. This, in turn, lowers the value of default option, and makes default less attractive when housing prices decline. Therefore, the second hypothesis can be formulated as

Hypothesis 2: Predatory lending laws lead to lower default rates in the subprime market.

was solved using MATLAB R2007b.

3 Stochastic Specification

The econometric approach to estimating subprime prepayments and defaults is based on the Kauermann and Khomski (2006) competing risk model with frailties and penalized splines smoothing. This model is based on the classical Cox approach[28] to modelling and estimating the hazard functions. The major advantage of this model, however, is that instead of assuming proportional hazards, it allows covariate effects to vary functionally with time. The baseline hazard is estimated explicitly, thus allowing all effects, including the baseline, to vary smoothly with time. A penalty is imposed on the spline coefficients to achieve a smooth fit.

The model investigates multiple duration times of the form$(t_{ij},\, d_{ij},\, x_{ij})$, $j = 1, ..., n_i$ for loan $i = 1, ..., n$, where x_{ij} is a set of covariates, t_{ij} is the duration of the loan and d_{ij} is the event marking termination of the loan.[29] There are 2 competing risks (prepayment and default), so that $d_{ij} = (d^P_{ij},\, d^D_{ij})$ is an indicator vector with $\{0,\, 1\}$ elements and $d^P_{ij} + d^D_{ij} \leq 1$. If $d^P_{ij} = 0$ and $d^D_{ij} = 0$ the observation is treated as censored.

The hazard function has the additive structure:

$$\lambda_i\left(t_{ij}, d_{ij}, x_{ij}\right) = \lambda^P(t_{ij}, x_{ij})w_{iP} + \lambda^D(t_{ij}, xi_j)w_{iD} \tag{21}$$

where $\lambda^l(\cdot)$ is the hazard due to event of type l with l ={P,D}, and w_{il} are (positive) frailty effects drawn from a multivariate distribution built from a mixture of independent gamma distribution components and having mean value one for identifiable reasons. The likelihood function for this problem is

$$L = \prod_{i=1}^{n}\prod_{j=1}^{n_i}\prod_{l=1}^{2}\left[\left\{\lambda^l\left(t_{ij}, x_{ij}\right)w_{il}\right\}^{d_{ijl}} \exp\left\{-\int_0^{t_{ij}} \lambda^l\left(u, x_{ij}\right)du \cdot w_{il}\right\}\right] \tag{22}$$

where the term under the exponent is a conditional survival function. The hazard components $\lambda^l(t, x)$ are modeled as

$$\lambda^l\left(t_{ij}, x_{ij}\right) = \exp\left\{\alpha_{lo}\left(t\right) + x_1\alpha_{l1p}\left(t\right) + ... + x_p\alpha_{lp}\left(t\right)\right\} \tag{23}$$

where $x = (x_1, ..., x_p)$is a set of covariates, $\alpha_{lr}\left(t\right)$ are time dynamic covariate effects, r = *1, . . . , p,* and

[28] Cox and Oakes (1984)

[29] The notation in this and following paragraph follows Kauermann and Khomski (2006).

$\alpha_{lo}(t)$ provides the baseline for the l-th risk. Both $\alpha_{lr}(t)$ are and $\alpha_{lo}(t)$ are approximated using penalized spline approach.[30] The likelihood function (22) is maximized via penalized likelihood method employing EM algorithm.[31]

This study also presents the estimates obtained imposing two restrictions of the Kauermann and Khomski (2006) competing risk model frequently used in the applied mortgage termination research. The first restriction assumes that baseline hazard components and frailty effects are additively separable, and the covariate effects are proportional to the baseline hazard. This introduces a proportional hazard model formulation (PHM) that allows correlated competing risks and accounts for the unobserved heterogeneity.[32] Though this restriction greatly reduces flexibility of the model it allows for computing the standard errors and evaluating statistical significance of the estimated coefficients.[33] The model then becomes Deng, Quigley and Van Order's (2000) econometric framework of mortgage termination by prepayment and default. The baseline hazard $\lambda^l(t, x)$ components are modeled as

$$\lambda^l(t_{ij}, x_{ij})\, w_{il} = \exp\{\alpha_l(t) + \beta_{li} x_i(t) + w_{il}\} \tag{24}$$

and the baseline $\alpha_l(t)$is parameterized as a quadratic function of the loan age:

$$\alpha_l(t) = \alpha_{l0} t + \alpha_{l1} t^2 \tag{25}$$

The likelihood function (22) is then maximized using the HHSM approach[34] for the proportional hazard model with grouped duration data.[35]

The second restriction assumes either independent competing risks or the absence of significant unobserved heterogeneity.[36] Then, for any joint survival function with arbitrary dependence between the competing risks, one can find a different survival function with independent survival times that has exactly the same

[30] See Kauermann and Khomski (2006) for details.

[31] The model was estimated in R statistical software using CompetingRiskFrailty package. The software and the package can be downloaded from http://www.cran.r-project.org/.

[32] Further in the text this model is referred as the "restricted model 1".

[33] In the unrestricted model covariates are the functions of time, therefore standard errors in a scalar form do not exist. The average standard errors can be computed from the point-wise confidence intervals.

[34] For a detailed description of HHSM approach see Deng, Quigley and van Order (2000), pp. 281-283.

[35] The model was estimated in SAS 9.1 for Windows statistical package, applying NLP procedure. The author thanks Anthony Pennington-Cross for sharing the source code used in Ho and Pennington-Cross (2006b).

[36] Further in the text this model is referred as the "restricted model 2".

cause-specific hazards.[37] This implies that, the data would not be able to distinguish a model with dependent competing risks from one with independent competing risks. Therefore, the model can be consistently estimated by fitting each of the competing risks separately, treating other risks as censored observations.[38] Thus, this restriction brings significant computational gains. Retaining a critical proportionality assumption in the absence of ties the likelihood function (22) becomes

$$L = \prod_{i=1}^{n} \prod_{l=1}^{2} \left\{ \frac{\exp \beta_{li} x_i (t)}{\sum\limits_{j \in R(t_i)} \exp \beta_{li} x_i (t)} \right\} \tag{26}$$

The model is estimated by maximum likelihood following the data augmentation method A, proposed by Lunn and McNeal (1995).[39]

4 Data

The data for this study are from the Financial Service Research Program's (FSRP) subprime mortgage database, which the Federal Reserve estimated to account for nearly a quarter of originations of higher priced home purchase and refinance mortgages on owner-occupied homes in 2004 (Avery, Canner, and Cook 2005).[40] The database contains loan-level data on all originations of subprime subsidiaries of eight large financial institutions between first quarter of 2001 and third quarter of 2003.

A unique feature of the database for analyzing delinquencies is that it is the only panel dataset that provides information on the annual percentage rate and the amount of points and fees for each loan—the information that the state laws use to define high-cost loans covered by the laws. The dataset also includes information on loan status (prepaid, paid, delinquent, or foreclosed), the status of delinquency (30 or more days due, 60 or more days due, etc.), and various consumer and loan characteristics.

The data are right-censored because not all loans in the sample terminated as of third quarter, 2003. To minimize the left-censoring problem, the data were split into four cohorts. Each of the cohorts comprises

[37] Tsiatis (1975)
[38] Kalbfleisch and Prentice (1980)
[39] The model was estimated in statistical package Stata 9.2
[40] Financial Services Research Program was formerly named Credit Research Center. The center changed its name when it moved to George Washington University in August 2006.

loans falling into a six month window since origination of the first loan in cohort. Thus, the loans in the first cohort originated in the period from January, 2001 to June, 2001, the loans in the second cohort originated in the period from July, 2001 to December, 2001, and so on. Analysis of cohorts endorsed in a narrow time period also reduces unobserved heterogeneity that enters as the time over which the loans were endorsed (e.g. changes in underwriting criteria based on prepayment and default experience). To avoid heterogeneities associated with the loan type and term structure, the analysis in this study is limited to the fixed-rate loans with 30-year term to maturity.[41]

Following Wallace (2007), this study considers a loan to be a default termination if it is reported foreclosed, in "Real Estate Owned (REO)" property, or deed-in-lieu regardless whether it was paid in full or not. The loan is not considered a default if foreclosure proceedings are initiated but not completed, because it can still be refinanced out of foreclosure. A loan is considered prepaid if it is reported paid-in-full prior to original due date, and not foreclosed or deed-in-lieu. Tabulations of loans by their status are reported in Table 1 (appendix 3).

Table 1: Variable Definitions

Variable Name	Description
status	Status: (active, prepaid, default)
call	Value of call option (refinance "in the money")
put	Value of put option (probability that homeowner's equity is negative)
fico	Fair Isaac credit score at origination
ownocc1	Owner occupied property (1=yes)
prepen1	Loan with prepayment penalty (1=yes)
broker	Broker originated loan (1=yes)
pmi	Borrower's payment to income ratio
urate	Current unemployment rate (by county)
unins	Current share of uninsured population (by county)
varint	Interest rate volatility for last 15 months
p1	Loan purpose: home purchase (1=yes)
p3	Loan purpose: cash-out refinance, debt consolidation (1=yes)
p4	Loan purpose: cash-out refinance, other purposes (1=yes)
p5	Loan purpose: refinance, No Cash-Out (1=yes)
regloan	Loan originated in "regulated" state
hc	"High-cost" loan
baseline	Estimated baseline hazard (models 1 and 2)
baselinesq	Estimated quadratic baseline hazard (model 2)

To estimate the monthly default and prepay probabilities specified in equations (22) and (24), this study considers various mortgage and market characteristics as covariates. The variables are described in table 1.

[41] These loans account for about 30 percent of originations in FSRP database.

Table 2 (appendix 3) provides some summary statistics for the estimation cohorts.

Options theory predicts that the borrower should exercise the option to call the debt whenever the market value of the mortgage exceeds the current balance by enough to cover the costs of refinancing. Following Ho and Pennington-Cross (2006b) the call option is calculated as the percentage reduction in the present value of future payments for the refinanced mortgage (PV_{jr}) relative to that for the current mortgage (PV_{jc}):

$$CALL = \frac{PV_{jc} - PV_{jr}}{PV_{jc}}, \tag{27}$$

$$\text{where } PV_{jc} = \sum_{m=0}^{TM} \left(i_j \times O \times \frac{(1+i_j)^{TM}}{(1+i_j)^{TM}-1} \right) \Big/ (1+d_j)^m, \tag{28}$$

$$\text{and } PV_{jr} = \sum_{m=0}^{TM} \left(r_j \times U \times \frac{(1+r_j)^{TM}}{(1+r_j)^{TM}-1} \right) \Big/ (1+d_j)^m \tag{29}$$

In equations (28) and (29), O is the original balance, U is the unpaid balance on the loan, TM is the remaining term on the mortgage, and i_j is the contract interest rate, and r_j is the market rate as defined by the Freddie Mac PMMS for that month, adjusted up by the fraction that the borrower's contract rate was above the prime rate at origination to reflect credit impairment. Thus one can anticipate prepayment probability for fixed-rate loans to increase when the value of the prepayment option is large.

A borrower may also put a mortgage when outstanding credit is greater than the value of the property after accounting for costs such as transaction fees. These are often referred to as "ruthless" defaults. Following Quigley, Deng, and Van Order (2000) this study calculates the put option as a probability that homeowner's equity is negative:[42]

$$PUT = \Phi \left(\frac{\log PV_{jc} - \log M_{jc}}{\sqrt{\omega^2}} \right) \tag{30}$$

In equation (30) PV_{jc} is the present value of future payments for the current mortgage, M_{jc} is property value at origination indexed by regional property price changes[43], and $\sqrt{\omega^2}$is the standard error of the OFHEO house price index.[44]

[42] This paper also attempted to measure put option using current loan-to-value ratio, which was highly correlated with results obtained using formula (30). The estimated coefficients on current loan-to-value ratio were similar to those obtained using put option calculated using formula (30).

[43] Regional property prices are measured by the Office of Federal Housing Enterprise Oversight (OFHEO) metropolitan area house price index.

[44] For details, see Calhoun (1996).

Based on the previous empirical literature the estimates include other factors that have been found to affect prepayments and defaults.[45] Borrower characteristics include the payment to income ratio and the Fair Isaac score (FICO). The FICO score predicts the likelihood of serious delinquency, bankruptcy, or other serious credit effect occurring in the next two years. Therefore, borrowers with higher credit scores are expected to default less often. Evidence from prime market data suggests that poor credit history[46] and high payment-to-income ratio[47] significantly reduces the probability of refinancing. Similarly, a borrower whose income or financial position deteriorates may be unable to refinance due to payment-to-income or credit quality constraints.

Loan characteristics include the dummy variables for loan purpose, prepayment penalty, and whether the home collateralizing the loan is owner-occupied. The costs of exercising the put option are higher for owner occupied loans, and cost of exercising the call option are higher for loans with prepayment penalties. Therefore, one might expect lower prepayment rates for these types of loans. Similarly, loans made to investors as opposed to owner occupants are more likely to end in a default. There is a mixed evidence about the effect of prepayment penalties on defaults of subprime mortgages.[48]

Distribution channel is captured by the broker origination dummy variable. The effect of this variable on prepayments and defaults is unclear. On one hand, mortgage brokers reduce informational costs and the interest rate gains from broker originated loans diminish the value of the call option, which deters prepayments. Lower interest rates also make it easier to make regular mortgage payments and may decrease defaults. On the other hand, agency issues involving different incentives of mortgage brokers, lenders and borrowers may cause broker-originated loans to prepay and default faster.[49]

Characteristics of the area housing and labor market are measured by the regional unemployment rates and regional shares of population without health insurance. Both variables are the proxies for trigger events

[45] Because of numerical complexity associated with estimating competing risk models with unobserved heterogeneity, several variables previously found to be important in explaining prepayments and defaults (e.g. state tax policy and foreclosure laws) were dropped from the final specification. Exclusion of these variables did not affect the results of this study.

[46] Bennett, Peach and Peristiani (2001)

[47] Archer, Ling and McGill (1996)

[48] Danis and Pennington-Cross (2005), and Quercia, Stegman, and Davis (2005) find that subprime loans with prepayment penalties are more likely to experience a foreclosure than loans without these characteristics. Mayer, Piskorski, and Tchistyi (2008) find that subprime borrowers with poor credit history default at a lower rate than comparable borrowers with no prepayment penalties.

[49] LaCour-Little and Chun (1999), Alexander, Grimshaw, McQueen and Slade (2002)

and macroeconomic conditions, which were found to increase defaults[50] and depress prepayments.[51]

The effect of regulation is captured by the dummy variable indicating whether the state in which loan was originated has adopted predatory lending legislation. At the time of origination of the first cohort, only two states (North Carolina and Massachusetts) had passed predatory lending legislation. The regulated states in the second cohort also include Connecticut, in the third cohort - Ohio, Pennsylvania, and Maryland, and in the fourth cohort - California, Florida, and Georgia.[52] Table 2 (appendix 3) shows that share of loans covered by state predatory lending laws increased dramatically from 3 percent in the beginning in of 2001 to 30 percent in the end of 2002.[53] Because most predatory lending laws imposed special requirements on loans defined as high-cost loans, this chapter includes the dummy variable for loans meeting the high-cost thresholds.[54]

5 Results

5.1 Effects of Regulation

The results largely meet expectations in terms of statistical significance and coefficient signs. Figures 1 – 4 (appendix 2) describe the results of non-parametric Kaplan-Meier analysis. Specifically, for each cohort the Kaplan-Meier survival function, and the cumulative default and prepay functions are reported. Each figure compares duration of regulated loans and unregulated loans per cohort.

Figures 1 - 4 show that subprime loans terminate fast – in first thirty months about 50 percent of the loans have been terminated, and in first twenty months about 30 percent of all loans are terminated. Subprime mortgages within the fourth cohort terminated at the fastest rate – about 40 percent in first 15 months.[55] The absolute majority of mortgage terminations are prepayments. These results are consistent with the

[50] Deng, Quigley and Van Order (1996)

[51] Caplin, Freeman and Tracy (1997)

[52] Because of relatively small share of regulated states this paper does not differentiate between restrictiveness of state laws. Among the states considered in this paper, North Carolina, Massachussets, California, and Georgia have passed relatively more restrictive laws. For more detailed analysis, see Ho and Pennington-Cross (2006a).

[53] Rules determining whether a loan is subject to regulation are based on a number of criteria and vary significantly across states. For a summary of these rules see Ho and Pennington-Cross (2006a).

[54] High-cost loans originated in states, which did not pass predatory lending legislation are defined according to HOEPA provisions.

[55] Because Kaplan-Meier survival functions are non-parametric, one cannot say whether the differences in termination rates across cohorts are statistically significant.

findings of the Ho and Pennington-Cross (2006b) study on terminations of subprime mortgages. The high rate of prepayment is also consistent with the interest rate dynamics in the neighborhood of the origination cohorts. According to Freddie Mac's Primary Mortgage Market Survey, the mortgage interest rates reached a 10 year low in 2003, so high values of the call option gave subprime borrowers strong incentives to refinance.[56]

Table 1 (appendix 3) shows that the share of defaults within cohorts were between 1.18 and 5.88 percent. The estimated rate of default was highest in the second cohort (5.88%), which is consistent with the poor performance of the U.S. economy in 2001-2002. Figures 1 - 4 also show that default rates increase rapidly around the tenth month after origination, indicating presence of administrative and time costs associated with loans going into foreclosure.

Figures 1 - 4 show that, across all cohorts, prepayment rates were higher for regulated loans (e.g. high-cost loans originated in the regulated states). This result is consistent with options theory – regulation increases the value of call option, and increases the likelihood of subprime refinancing. As regards the defaults, figures suggest that the early foreclosures were higher and late foreclosures were lower for regulated loans, which might indicate persistence in implementation of some provisions (e.g. disclosure requirements) of state predatory lending laws.

Table 2: Effect of Credit Regulation - Prepayments

Model	Cohorts			
	1	2	3	4
Unrestricted model (intercept)	0.07	-0.37	0.44	-0.13
Unrestricted model slope	0.11	0.19	0.04	0.04
Restricted model 1 (intercept)	**0.93**	**0.92**	**0.53**	-0.01
Restricted model 2 (intercept)	**1.14**	**0.91**	**0.69**	**0.35**

Note. Standard errors and significance levels are not available for the unrestricted model, but the point-wise confidence intervals are reported in a technical appendix available from author. Coefficients in bold show estimated model coefficients found to be statistically significant in restrictive models (at 5% level).

Table (2) shows the estimated coefficients in the prepayment equation on the dummy variable indicating whether the state in which loan was originated passed predatory lending legislation. The results across all

[56] Subprime borrowers with very poor credit histories might not qualify for refinance at lower interest rates.

models almost unanimously indicate that prepayment rates were higher in the regulated states. The unrestricted model indicates that in second and fourth cohorts prepayments are initially lower in regulated states but they increase faster with the duration of the loan. The restricted model 1 indicates that prepayments are lower in regulated states in fourth cohort, but the estimated coefficient is not statistically significant.

Table 3: Effect of Credit Regulation - Defaults

Model	Cohorts			
	1	2	3	4
Unrestricted model (intercept)	2.95	0.55	-0.72	-1.04
Unrestricted model slope	-0.12	-0.05	0.09	0.18
Restricted model 1 (intercept)	0.27	0.14	0.18	0.04
Restricted model 2 (intercept)	**-0.84**	**-0.55**	-0.17	**-0.38**

Note. Standard errors and significance levels are not available for the unrestricted model, but the point-wise confidence intervals are reported in a technical appendix available from author. Coefficients in bold show estimated model coefficients found to be statistically significant in restrictive models (at 5% level).

Table (3) shows the estimated coefficients in the default equation of the dummy variable indicating whether the state in which loan was originated adopted predatory lending legislation. The differences across the estimates in the default equation indicate the importance of the restrictions imposed by the models. Because the models were estimated by maximizing different likelihood functions, and applying different algorithms, these restrictions cannot be easily tested. Some inferences can be made, however by comparing the direction, size and significance of the estimated coefficients. For example, the differences across the estimates in the restricted models 1 and 2 indicate that the results are sensitive to addition of the unobserved heterogeneity assumption, and thus restrictive model 1 is more robust. As noted above, both the restricted models 1 and 2 found that prepayment rates are higher in regulated states. Because the restricted model 2 treats prepayment and default risks as completely independent it does not use this information. If the competing risks of prepayment and default are negatively correlated, the prediction from the restrictive model 1 then may indicate that a significant share of bad loans in regulated states were refinanced out of default. The results from the unrestricted model show that early defaults, which are more likely associated with fraudulent loans[57] decrease as regulation coverage increases. These results are consistent with the findings from the study of Ho and Pennington-Cross (2006a), which indicate that the volume of subprime originations from riskiest segments of subprime market declined in the states that passed restrictive predatory lending laws. This implies that the regulation can be welfare enhancing if it covers larger number of states.

The results from both restricted models 1 and 2 (tables 3 to 8, appendix 3) indicate that high-cost loans prepay at a lower rate. This result is in line with previous findings that prepayments of low cost loans were more sensitive to interest rate reductions between 2001 and 2003.[58] The results from unrestricted model show that the probability of high-cost loan prepayments and defaults diminishes over time, demonstrating the effect of tightened regulation of the high-cost segment of subprime market.

5.2 Effects of Other Variables

Tables 3 to 8 (appendix 3) report the estimated coefficients for prepayment and default equations from the unrestricted and restricted models across all four cohorts. The results are generally consistent with the predictions of options theory. The unrestricted model estimates indicate that the value of the call option is a better predictor for relatively late prepayments. In the restricted models the estimated coefficients for the call option in the prepayment equation were positive and significant in almost all cases. The results from the unrestricted model show that the value of the put option has a strong positive effect on earlier defaults, which decreases with loan duration. The estimated coefficients for put option in default equation were positive and significant in the restricted model 2 and not statistically significant in restricted model 1 specifications.

The results for other control variables are generally consistent with the results from previous studies. Estimated coefficients on FICO score were positive and significant in prepayment equation and negative and significant in the default equation across almost all cohorts in both restricted models 1 and 2. The results from the unrestricted model show that the effect of past credit history on prepayments and defaults decreases as loan's duration increases.

[57] According to the research done by BasePoint Analytics (2008), as much as 70 percent of recent early payment defaults had fraudulent misrepresentations on their original loan applications.

[58] Cutts and Van Order (2005, pp. 173-174).

The estimated coefficients on the borrower's payment-to-income ratio were varying in terms of sign across both models and cohorts. The unrestricted model suggests rapid increase in prepayments for borrowers with high payment to income ratio in first three cohorts. The estimated coefficients in the prepayment equation were positive and significant across first three cohorts in both restricted models 1 and 2.

Evidence from these cohorts contradicts findings from prime market data, discussed in the previous section, and illustrates an important difference between prime and subprime markets. In the prime market, an income shock impedes refinancing because it makes more difficult for a borrower to qualify for a lower interest rate. On the subprime market the burden of most expensive loans is usually too large to be sustainable, so subprime borrowers with high payment to income ratios would choose to refinance should their credit history improve, and default otherwise.

As expected, the unrestricted model suggests that the risk of default for high payment to income ratio is a strong predictor of default. The estimated coefficients on payment to income ratio were negative and significant across first three cohorts in the restricted model 2, and positive and significant across all cohorts in the restricted model 1 and the last cohort in the restricted model 1. The differences between restricted models 1 and 2 again reflect the size of the bias due to omitted unobserved heterogeneity.

Consistent with earlier studies, owner-occupied loans and home-purchased loans were associated with negative and significant coefficients in the default equation across all models and cohorts. The unrestricted model suggests that this impact becomes less pronounced as duration of the loan increases. The coefficients in the prepayment equation for owner occupied loans were also negative (except for the last cohort). The coefficients for both home-purchased loans and non cash-out refinanced loans were positive, significant, and about the same value in absolute terms. The results indicate that probability of prepayment is lower for cash-out refinanced loans, especially those taken for debt consolidation. Similarly to the default equation, the unrestricted model suggests that prepayment risk decreases with the duration of the loan for home-purchased loans and non cash-out refinanced loans.

Loans subject to prepayment penalties were associated with positive and significant coefficient in the prepayment equation across all cohorts and model specifications. The estimated coefficients on prepayment penalty dummy in the default equation are negative and significant in restricted model 2, and vary across cohorts in restricted model 1. The unrestricted model suggests that loans subject to prepayment penalties are less likely to go into earlier defaults but the hazard increases with the duration of the loan. Though these results contradict earlier findings, they probably reflect the selection bias as part of the borrowers with prepayment penalties represent different segment of the subprime market and have higher loan-to-value and payment to income ratios.[59]

Broker originated loans are associated with negative and significant coefficients in both prepayment and default equations across all cohorts in both restricted models. This result may indicate that informational efficiency gains from mortgage brokers outweigh agency costs associated with different incentives of mortgage brokers, lenders, and borrowers.[60]

Consistently with earlier findings on the effect of trigger events on prepayments and defaults, higher regional shares of uninsured population are associated with positive coefficients in default equations and negative and significant coefficient in prepayment equations across most cohorts in both restricted models. The results in the default equation were typically not statistically significant in restricted model 1. The unrestricted model suggests that default and prepayment risk due to a large fraction of uninsured population decreases over time. The estimated coefficients on regional unemployment rates were mostly statistically non-significant in both prepayment and default equations and their signs varied across cohorts in both restricted models. The signs of the intercept and slope coefficients in both prepayment and default equations varied also in the unrestricted model.

6 Conclusions

This study analyzed the effects of state predatory lending laws on prepayments and defaults of subprime mortgages. Two hypotheses were formulated based on the theoretical model, which used the option-pricing model of mortgage valuation. The first hypothesis proposed that state predatory lending laws would result in increase of prepayments in the subprime market. The second hypothesis suggested that state predatory lending laws would result in decrease of defaults in the subprime market.

[59] See Steinbuks (2008).

[60] Evidence from FSRP subprime database indicates that broker originated loans are associated with lower loan prices (measured by APR adjusted for brokerage fees).

These hypotheses were tested using competing risks models of mortgage termination that predicted probabilities of prepayment and default on 30-year fixed-rate subprime mortgage data. Controlling for other factors, the estimated probabilities of prepayment were found to be higher in the states that have introduced predatory lending laws. Though no definite conclusions could be drawn regarding the effect of state laws on subprime defaults, there is some evidence that early defaults decreased as the extent of regulatory scope expanded. The results of these models were generally consistent with the predictions of the options theory, and previous empirical literature on mortgage termination.

These results indicate that restrictions on prepayment penalties lowered default rates and raised prepayment rates because they affected the structure of an optimal mortgage contract. This resulted in an increase of the value of borrower's prepayment option and decline in the value of borrower's default option, making prepayments more likely, and defaults less likely to happen.

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Appendix 1

Figure 1: Value of Future Payments (A)

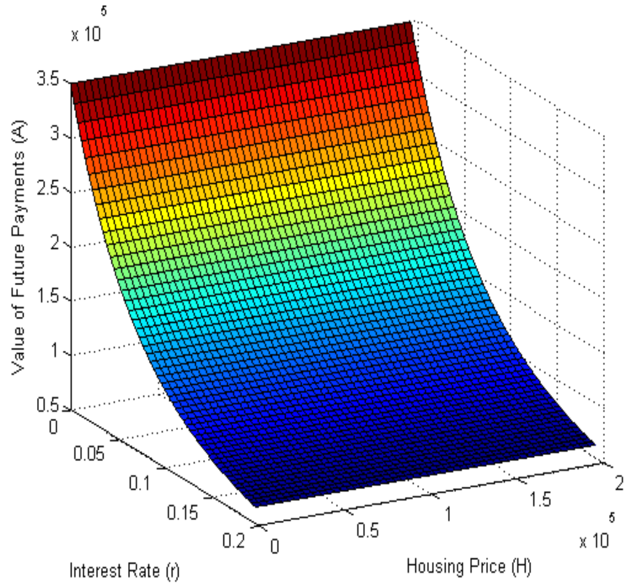


Figure 2: Mortgage Value (V)

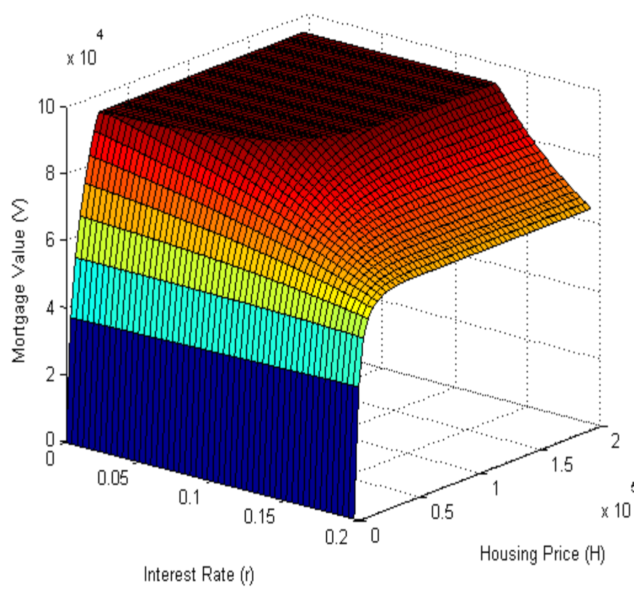


Figure 3: Value of Prepayment Option (C)

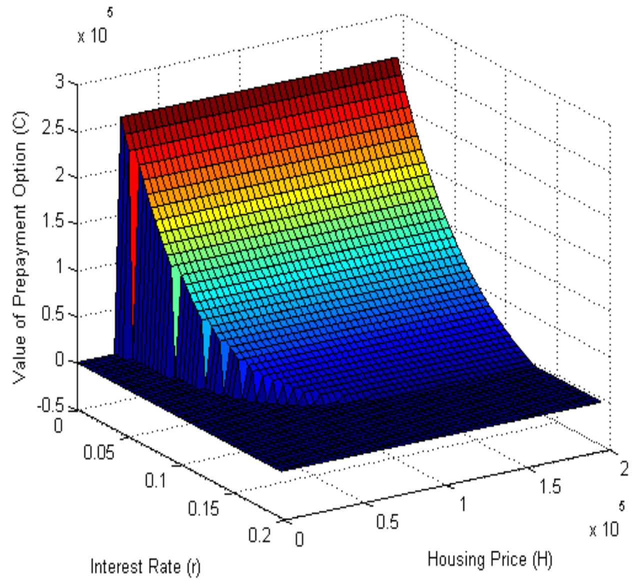
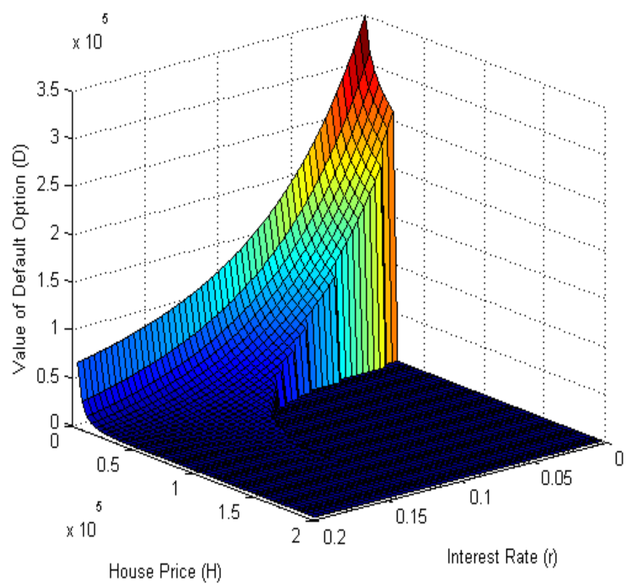


Figure 4: Value of Default Option (D)



Appendix 2

Figure 1: Termination of Fixed Loans, Cohort 1 (January, 2001 – June, 2001)

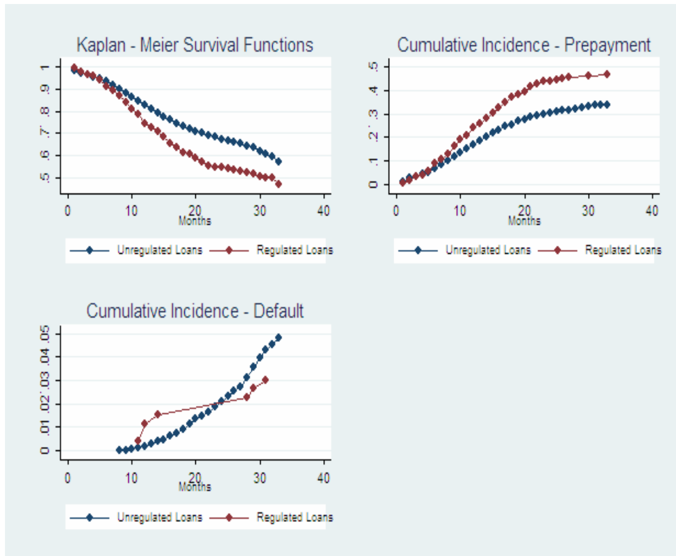


Figure 2: Termination of Fixed Loans, Cohort 2 (June, 2001 – December, 2001)

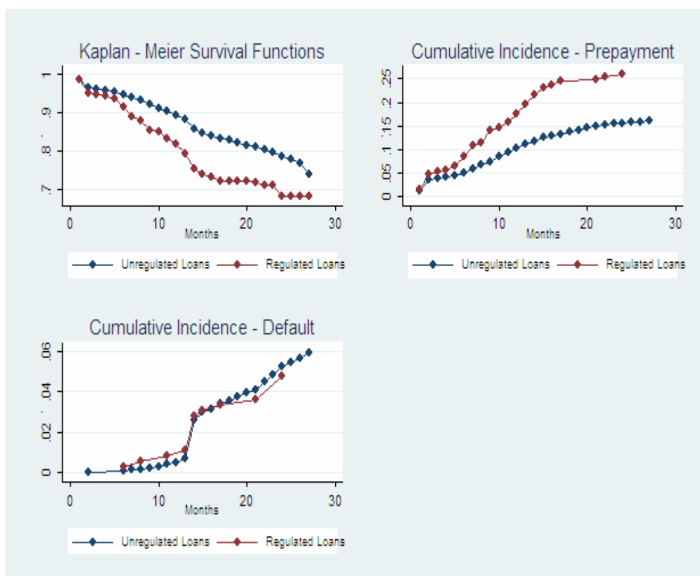


Figure 3: Termination of Fixed Loans, Cohort 3 (January, 2002 – June, 2002)

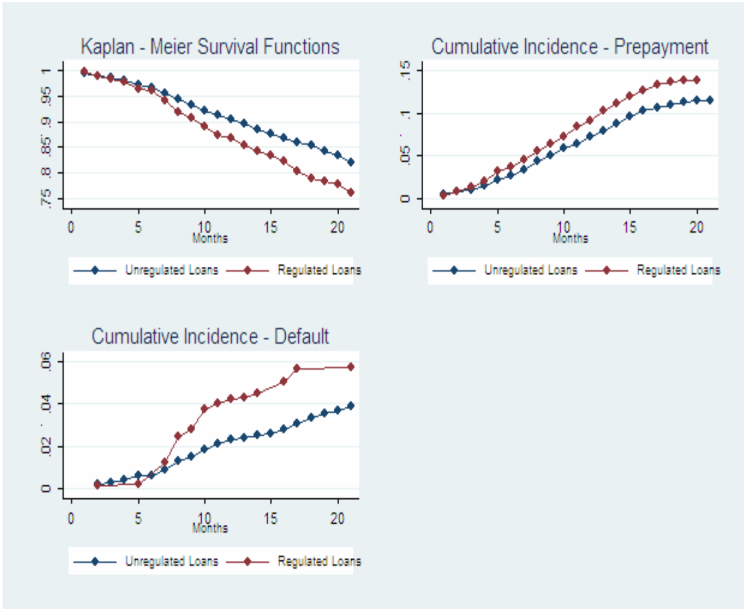
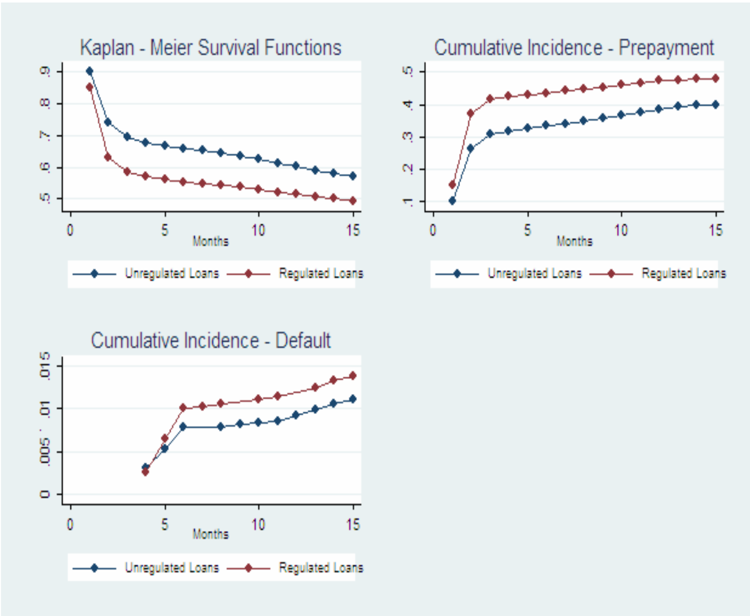


Figure 4: Termination of Fixed Loans, Cohort 4 (June, 2002 – December, 2002)



Appendix 3

Table 1: Loans' Status (October, 2003)

Status	Cohorts							
	1		2		3		4	
	Obs	**Freq**	**Obs**	**freq**	**obs**	**Freq**	**obs**	**Freq**
Active	6,105	60.96	9,083	77.85	14,744	84.29	11,528	56.54
Prepaid	3,434	34.29	1,899	16.28	2,041	11.67	8,621	42.28
Default	475	4.74	686	5.88	706	4.04	241	1.18

Table 2: Descriptive Statistics

Variable	Cohorts							
	1		2		3		4	
	Mean	**std.**	**mean**	**std.**	**mean**	**Std.**	**mean**	**Std.**
call	0.38	0.07	0.27	0.10	0.25	0.11	0.19	0.12
put	0.69	0.16	0.65	0.18	0.62	0.19	0.58	0.18
fico	595	60	599	57	599	59	598	58
ownocc1	0.93	0.26	0.89	0.32	0.88	0.32	0.85	0.36
prepen1	0.44	0.50	0.38	0.48	0.48	0.50	0.56	0.50
broker	0.16	0.36	0.28	0.45	0.35	0.48	0.44	0.50
pmi	0.27	0.15	0.24	0.12	0.24	0.12	0.23	0.12
urate	6.03	1.46	5.55	1.41	6.16	1.37	6.31	1.47
unins	14.31	4.54	14.12	4.56	14.60	4.44	15.29	4.53
p1	0.06	0.23	0.06	0.23	0.05	0.23	0.06	0.24
p4	0.32	0.47	0.24	0.43	0.20	0.40	0.18	0.39
p5	0.08	0.28	0.21	0.41	0.28	0.45	0.40	0.49
regloan	0.03	0.16	0.03	0.17	0.07	0.26	0.30	0.46
hc	0.71	0.45	0.82	0.39	0.78	0.41	0.79	0.41

Table 3: Model 1 (penalized spline baseline hazard approximation) - prepayments

Variable	Cohorts							
	1		2		3		4	
	intercept	**slope**	**intercept**	**Slope**	**Intercept**	**slope**	**intercept**	**slope**
call	-13.51	1.65	-17.13	3.11	-10.01	4.76	-7.13	-1.97
put	3.00	-0.70	1.52	-0.58	0.60	-0.74	1.15	0.41
fico	-0.002	0.001	-0.01	0.002	-0.001	0.001	-0.002	-0.002
ownocc1	0.83	-0.07	1.96	-0.33	0.87	-0.21	0.29	0.25
prepen1	-0.22	0.05	0.50	-0.05	0.37	0.02	0.54	0.00
broker	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
pmi	-1.50	1.56	-0.68	3.42	20.44	0.42	-19.72	-1.52
urate	-0.20	-0.14	-0.30	-0.11	0.69	-0.14	0.03	0.00
unins	0.02	-0.01	0.10	-0.02	-0.04	0.00	0.03	0.00
P1	2.88	-0.63	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
P4	0.83	-0.08	-0.84	0.21	0.06	0.03	-0.08	0.02
P5	4.23	-0.73	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
regloan	0.07	0.11	-0.37	0.19	0.44	0.04	-0.13	0.04
hc	0.45	-0.11	1.00	-0.27	-0.40	-0.05	0.55	-0.11
baseline	-2.17	0.77	3.25	-0.42	-7.64	-0.20	-1.55	0.81
LL	-20763.5		-14464.6		-16015.7		-32176.6	

Table 4: Model 1 (penalized spline baseline hazard approximation) - defaults

Variable	Cohorts							
	1		2		3		4	
	intercept	**slope**	**intercept**	**Slope**	**Intercept**	**slope**	**intercept**	**Slope**
call	-13.51	1.65	-17.13	3.11	-10.01	4.76	-7.13	-1.97
put	3.00	-0.70	1.52	-0.58	0.60	-0.74	1.15	0.41
fico	-0.002	0.001	-0.01	0.002	-0.001	0.001	-0.002	-0.002
ownocc1	0.83	-0.07	1.96	-0.33	0.87	-0.21	0.29	0.25
prepen1	-0.22	0.05	0.50	-0.05	0.37	0.02	0.54	0.00
broker	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
pmi	-1.50	1.56	-0.68	3.42	20.44	0.42	-19.72	-1.52
urate	-0.20	-0.14	-0.30	-0.11	0.69	-0.14	0.03	0.00
unins	0.02	-0.01	0.10	-0.02	-0.04	0.00	0.03	0.00
P1	2.88	-0.63	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
P4	0.83	-0.08	-0.84	0.21	0.06	0.03	-0.08	0.02
P5	4.23	-0.73	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
regloan	0.07	0.11	-0.37	0.19	0.44	0.04	-0.13	0.04
hc	0.45	-0.11	1.00	-0.27	-0.40	-0.05	0.55	-0.11
baseline	-2.17	0.77	3.25	-0.42	-7.64	-0.20	-1.55	0.81
LL	-6823.9		-4040.8		-16015.7		-32176.6	

Table 5: Model 2 (quadratic polynomial baseline hazard approximation) – prepayments

Variable	Cohorts							
	1		2		3		4	
	coeff.	**p-value**	**coeff.**	**p-value**	**coeff.**	**p-value**	**coeff.**	**p-value**
call	4.86	0.00	5.00	0.00	5.71	0.00	-3.10	0.00
put	-1.23	0.00	-1.49	0.00	-2.68	0.00	-0.60	0.00
fico	0.002	0.00	0.001	0.077	0.002	0.00	-0.002	0.00
ownocc1	-0.10	0.30	-0.18	0.06	-0.11	0.36	0.48	0.00
prepen1	0.67	0.00	0.65	0.00	0.89	0.00	0.59	0.00
broker	-1.37	0.00	-0.86	0.00	-2.27	0.00	n.a.	n.a.
pmi	8.80	0.00	11.85	0.00	13.91	0.00	-6.60	0.00
urate	0.01	0.52	0.06	0.00	0.03	0.04	-0.01	0.50
unins	-0.03	0.00	-0.02	0.00	-0.02	0.01	0.03	0.00
P1	0.53	0.00	0.69	0.00	-0.01	0.97	n.a.	n.a.
P4	0.27	0.00	0.47	0.00	0.16	0.00	0.02	0.47
P5	0.62	0.00	0.57	0.00	-0.98	0.00	n.a.	n.a.
regloan	0.93	0.00	0.92	0.00	0.53	0.00	-0.01	0.65
hc	-0.66	0.00	-0.84	0.00	-0.43	0.00	0.16	0.00
baseline	0.11	0.00	-0.02	0.20	0.17	0.00	-0.51	0.00
baselinesq	-0.004	0.00	-0.001	0.01	-0.01	0.00	0.02	0.00
LL	-19704.3		-13774.9		-14046.8		-30407.5	

Table 6: Model 2 (quadratic polynomial baseline hazard approximation) – defaults

Variable	Cohorts							
	1		2		3		4	
	Coeff.	**p-value**	**coeff.**	**p-value**	**coeff.**	**p-value**	**coeff.**	**p-value**
call	2.29	0.02	-2.72	0.00	1.06	0.17	-8.28	0.00
put	0.10	0.80	-0.62	0.11	-0.37	0.27	1.35	0.02
fico	-0.01	0.00	-0.01	0.00	-0.01	0.00	-0.01	0.00
ownocc1	-1.13	0.00	-4.58	0.00	-6.38	0.00	-6.27	0.00
prepen1	0.33	0.01	-0.03	0.86	-0.21	0.18	-4.15	0.00
broker	-2.72	0.00	-2.91	0.00	-6.70	0.00	n.a.	n.a.
pmi	14.60	0.00	10.46	0.07	5.20	0.26	35.77	0.00
urate	-0.24	0.00	0.02	0.65	-0.07	0.06	-0.11	0.08
unins	0.03	0.02	0.01	0.17	0.01	0.22	0.01	0.74
P1	-0.89	0.02	-3.43	0.00	-5.98	0.00	n.a.	n.a.
P4	0.40	0.00	-0.09	0.58	0.09	0.58	0.97	0.01
P5	-1.34	0.00	-2.75	0.00	-6.36	0.00	n.a.	n.a.
regloan	0.27	0.50	0.14	0.61	0.18	0.24	0.04	0.79
hc	-0.64	0.00	-0.51	0.00	-0.15	0.32	-0.94	0.00
baseline	0.23	0.00	0.53	0.00	0.23	0.00	1.09	0.00
baselinesq	-0.001	0.20	-0.01	0.00	0.004	0.01	-0.03	0.00
LL	-19704.3		-13774.9		-14046.8		-30407.5	

Table 7: Model 3 (baseline hazard not estimated) – prepayments

Variable	Cohorts							
	1		2		3		4	
	Coeff.	**p-value**	**coeff.**	**p-value**	**coeff.**	**p-value**	**coeff.**	**p-value**
call	-0.04	0.06	0.23	0.00	0.41	0.00	0.42	0.00
put	-0.04	0.00	-0.10	0.00	-0.18	0.00	-0.01	0.81
fico	0.001	0.03	-0.001	0.00	0.001	0.17	0.002	0.00
ownocc1	0.02	0.86	-0.38	0.00	-0.43	0.00	0.29	0.00
prepen1	0.79	0.00	0.65	0.00	0.97	0.00	0.28	0.00
broker	-1.80	0.00	-1.02	0.00	-2.40	0.00	0.76	0.00
pmi	10.76	0.00	15.13	0.00	13.38	0.00	-0.98	0.54
urate	-0.01	0.00	-0.01	0.00	0.003	0.03	0.005	0.02
unins	-0.001	0.00	-0.005	0.00	-0.002	0.00	-0.01	0.00
P1	0.28	0.04	0.59	0.00	-0.23	0.21	1.53	0.00
P4	0.38	0.00	0.62	0.00	0.17	0.01	1.17	0.00
P5	0.34	0.00	0.47	0.00	-1.16	0.00	1.68	0.00
regloan	1.14	0.00	0.91	0.00	0.69	0.00	0.35	0.00
hc	-0.60	0.00	-0.88	0.00	-0.42	0.00	-0.04	0.34
LL	-44222.4		-29014.9		-30262.1		-100875.2	

Table 8: Model 3 (baseline hazard not estimated) – defaults

Variable	Cohorts							
	1		2		3		4	
	Coeff.	**p-value**	**coeff.**	**p-value**	**coeff.**	**p-value**	**coeff.**	**p-value**
call	0.17	0.00	-0.54	0.00	-0.44	0.00	-0.72	0.00
put	0.09	0.00	0.20	0.00	0.29	0.00	0.28	0.00
fico	-0.01	0.00	-0.001	0.06	0.002	0.00	-0.001	0.02
ownocc1	-0.57	0.02	-2.76	0.00	-3.32	0.00	-3.97	0.00
prepen1	-0.48	0.00	-0.42	0.01	-1.66	0.00	-1.83	0.00
broker	-0.72	0.04	-1.22	0.00	-1.67	0.02	-36.21	0.00
pmi	-3.43	0.17	-26.99	0.00	-15.89	0.00	13.07	0.03
urate	0.001	0.48	0.01	0.00	-0.01	0.01	0.01	0.07
unins	0.003	0.00	0.01	0.00	0.01	0.00	0.01	0.00
P1	-0.86	0.03	-3.16	0.00	-3.30	0.00	-38.63	0.00
P4	-0.01	0.92	-1.18	0.00	-0.75	0.00	-0.63	0.07
P5	-1.28	0.00	-2.76	0.00	-2.74	0.00	-4.50	0.00
regloan	-0.84	0.03	-0.55	0.05	-0.17	0.33	-0.38	0.02
hc	-0.01	0.94	0.58	0.00	0.49	0.00	0.06	0.84
LL	-44222.4		-29014.9		-30262.1		-100875.2	