STRUCTURAL CHANGE IN THE MORTGAGE MARKET AND THE PROPENSITY TO REFINANCE

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Abstract: We hypothesize that the intrinsic benefit required to trigger a refinancing has become smaller, due to a combination of technological, regulatory, and structural changes that have made mortgage origination more competitive and more efficient. To test this hypothesis, we estimate an empirical hazard model of loan survival for two subperiods, using a database that allows us to carefully control for homeowners' credit ratings, equity, loan size, and measurable transaction costs. Our findings strongly confirm that credit ratings and home equity have significant effects on the refinancing probability. In addition, we provide evidence that homeowners postpone refinancing in the face of increased interest rate volatility, consistent with option value theory. Finally, our results clearly support the hypothesis that structural change in the mortgage market has increased homeowners' propensity to refinance.

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1. INTRODUCTION

A primary consideration in the pricing of residential mortgage loan assets is prepayment risk--the premature or unscheduled return of principal to investors when homeowners move, refinance, or default. Prepayment speeds have increased in the 1990s relative to the 1980s, and this increase cannot be easily explained by changes in the variables normally used to explain prepayment behavior. We hypothesize that this increase in prepayment speeds is the result of changes in the structure of the mortgage market, which have reduced transactions costs or "frictions" associated with obtaining a mortgage loan. On the supply side, over the past twenty-five years the U.S. housing finance system has undergone a fundamental restructuring such that today it is both more competitive and more fully integrated with the general capital market.

This paper presents a formal test of the hypothesis that the propensity to refinance has increased over time due to a decline in transaction costs or "frictions", broadly defined. Conducting such a test represents a considerable challenge. A considerable body of literature has demonstrated quite convincingly that prepayment behavior in general, and refinancing behavior in particular, cannot be adequately explained by financial variables alone, but rather is strongly influenced by individual borrower and property characteristics (see Archer, Ling, and McGill 1996; Caplin, Freeman, and Tracy 1997; Peristiani, Bennett, Monsen, Peach, and Raiff 1997). These studies find that in addition to changes in interest rates and transaction costs, individual homeowners' equity and credit histories play an important role in determining the probability that a mortgage will be refinanced. Accordingly, a convincing empirical test of this hypothesis must be based on loan level data that captures these individual borrower characteristics and which identifies the reason for loan prepayment. Furthermore, this loan level data must cover homeowner behavior over an extended time period. As is discussed more fully below, the analysis presented in this paper is based on a unique data set that meets all of these criteria.

The primary empirical findings of this analysis can be summarized as follows. First, the results reconfirm the importance of individual borrower and property characteristics in prepayment behavior. Second, we also find that homeowners delay refinancing as interest rate volatility increases, consistent with option valuation theory. Finally, and most importantly in terms of the goals of this paper, the analysis strongly supports the hypothesis that structural changes in the mortgage market have made homeowners more inclined to refinance in the 1990s than in the 1980s, controlling for interest rate levels and volatility, points and fees, and homeowners' equity and credit histories.

The plan of the paper is as follows. Section 2 discusses the evolution of the housing finance system. Section 3 presents the theory of the optimal refinance decision rule. Section 4 describes the data set used in this analysis. Section 5 presents our model specification and defines the explanatory variables. Section 6 presents the empirical results of the model estimation. The paper closes with a brief summary of our findings.

2. THE EVOLUTION OF THE HOUSING FINANCE SYSTEM

The prepayment experience of mortgage securities during the 1980s and 1990s is illustrated by Figure 1, which presents prepayments speeds for unseasoned, moderately seasoned, and seasoned Fannie Mae mortgage backed securities (MBS) backed by 30 year fixed-rate mortgages. As seen from the figure, the MBS market experienced two major refinancing cycles over the past two decades, 1986-87 and 1992-93, both of which were prompted by steep declines in long-term interest rates. Despite the fact that the decline in mortgage interest rates from 1983-

1984 to early 1987 was somewhat greater than the decline that occurred from 1990 to late 1993, prepayments appear to be somewhat higher in the 1990s refinancing waves than was the case in the 1986-1987 wave. In fact, in early 1998, when mortgage interest rates returned to the levels that prevailed in late 1993, the magnitude of the surge in refinancing activity surprised many industry analysts. Indeed, the secular rise of prepayment speeds has led to the recent introduction of prepayment protection mortgages, where in return for a somewhat lower interest rate borrowers agree to a prepayment penalty under specific circumstances.

Several factors may have contributed to the differing intensity of these refinancing cycles. Lekkas (1993) shows that refinancers in the 1986-87 episode were primarily concerned with lowering monthly mortgage payments. In contrast, during the 1992-93 episode, refinancers tended to shorten the maturity of their mortgage rather than simply lower monthly payments. While these findings suggest some subtle differences on the demand-side of refinancings, Figure 2 suggests that changes on the supply side of the mortgage market may also have played an important role. In the 1970s, the provision of long-term financing to homeowners was dominated by portfolio lenders, primarily thrift institutions. Due to a complex combination of economic and regulatory changes as well as financial and technological innovations, today mortgage lending is dominated by mortgage bankers/brokers and the process of securitization. An important distinction between these two systems is that the former, often referred to as the New Deal system, effectively limited competition among lenders. In contrast, the modern system has eliminated most geographic and financial barriers to entry and so is considerably more competitive (see, for example, Hendershott 1992).

Increased competition in the primary mortgage market along with improvements in information processing technology have lowered the explicit, financial transactions costs associated with obtaining a mortgage, as reflected in the secular decline in average points and fees on conventional loans closed. Nonfinancial transactions costs have also declined; the mortgage application and approval process has been streamlined, resulting in shortened time intervals from application to approval and approval to closing, and lending programs with substantially reduced financial documentation in the application process have emerged. Furthermore, advances in computer technology have enabled lenders to quickly and cheaply identify and contact mortgagors with interest rates above prevailing market rates, thereby disseminating information about refinancing opportunities more quickly and broadly than occurred in the past. In addition, the development and growth of the subprime mortgage market has established a flow of credit to borrowers unable to meet the underwriting criteria of the government sponsored enterprises (GSEs). Finally, reinforcing these developments on the supply side of the market, homeowners have likely become more financially savvy, increasing their propensity to refinance for a given set of measurable incentives.

3. THE THEORY OF OPTIMAL PREPAYMENT

Unlike many other fixed income instruments, the standard mortgage contract typically includes the unrestricted right to prepay or call the loan at any time. For this reason, a mortgage is viewed as the combination of a noncallable bond and a call option (see Follain, Scott, and Yang 1992; Archer, Ling, and McGill 1997). Exercising the call option now likely means forgoing refinancing in the near future at a possibly lower interest rate since the transactions costs associated with obtaining a new mortgage would have to be incurred again. Accordingly, the decision to refinance involves the comparison of the benefits of refinancing at current interest rates--the intrinsic value--against the costs--transactions costs and the opportunity cost of exercising an option now rather than later.

When the present value of an existing mortgage liability exceeds the present value of a replacement loan by at least the total of all transaction costs associated with obtaining the replacement mortgage, homeownership financing costs will be reduced by refinancing. Suppose that borrower (i) takes out a mortgage loan at calendar month t_{0i} and that the borrower expects to make payments on that loan until some future terminal date, T_i, which is equal to or less than the full maturity of the loan. Let $B(T_i,t,r)$ represent the present value of the noncallable, fully-amortizing bond with coupon rate (r) at calendar month t $(t=t_{0i},...,T_i)$. Also, let $V(T,t,\sigma_t)$ denote the value of the embedded call option at period t. The value of this option, often referred to as the "time value" of the mortgage, depends on the expected holding period of the mortgage $(T-t)$ and the expected future volatility of the noncallable asset (σ_t). A household seeking to minimize the present value of its mortgage financing costs will prepay the existing mortgage if

$$B(T_i,t,r_{ci}) - B(T_i,t,r_{mti}) > TC_{ti} + \upsilon(T_i,t,\sigma_t), \qquad \textbf{(1)}$$

where

$$\upsilon(T_i,t,\sigma_t) = V_c(T_i,t,\sigma_t) - V_m(T_i,t,\sigma_t). \qquad \textbf{(2)}$$

Here, (r_{ci}) represents the existing mortgage rate, (r_{mti}) is the prevailing market rate, and (TC_{ti}) equals the sum of points, fees and all other costs or "frictions" associated with obtaining the replacement financing. The left-hand-side of equation (1) represents the "intrinsic value" of refinancing or the financial gain from refinancing at the currently prevailing market interest rate.

The variable $\upsilon(T_i,t,\sigma_t)$, which we label the *option replacement cost*, represents the difference between the time value of the call option in the existing mortgage $V_c(T_i,t,\sigma_t)$, which presumably is “near-”, “at-”, or “in-” the money, and the time value of the call option in the replacement loan $V_m(T_i,t,\sigma_t)$, which is presumably well “out of the money” due to transaction costs. An increase in expected future volatility increases the value of both of these options. However, an increase in expected future volatility increases the value of the at- or near-the-money option--the option embedded in the existing mortgage--more than it increases the value of a well out-of-the-money option--the option in the replacement financing (see Hull 1993). For this reason, an increase in expected future volatility raises the cost and so reduces the likelihood that a loan will be refinanced. While empirical evidence of this effect has been elusive, Giliberto and Thibodeau (1989) find that increased interest rate volatility lowers the likelihood of prepayment.

Transaction Costs

While the intrinsic value of a loan and the option replacement cost are based strictly on past, present, and expected future interest rates, transaction costs (TC_{ti}) reflect a mix of market conditions and individual borrower and property characteristics. Some of these transaction costs can be quantified, others cannot. Conceptually, transaction costs can be divided into a number of distinct components: (1) direct, out-of-pocket expenses associated with prepaying the existing loan and obtaining replacement financing (e.g., points and fees, prepayment penalties, and legal expenses) (TC_{POINTS}); (2) additional out-of-pocket expenses, such as higher points and/or interest rate, and additional documentation required because of a poor credit rating or score (TC_{CREDIT}); (3) costs such as mortgage insurance that may result from low equity in the property (TC_{LTV}); and finally (4) “frictions” that may reflect factors such as the opportunity cost of the time that must be invested in shopping for a lender and applying for the mortgage as well as the relative level of financial sophistication of the borrower $(TC_{FRICTION})$. The first component of transaction costs--points and fees--have fallen over time, from 2.5 percent of the average conventional loan amount in 1983 to around 1 percent at the end of 1995, likely reflecting both technological innovation and increased competition in the primary mortgage market. Transactions costs associated with poor credit ratings may also have been reduced by innovations such as credit scoring, which provide lenders with a more efficient basis for pricing credit risk, as evidenced by the rise of subprime lending. Finally, the costs of searching for and comparing different lenders and the burden of completing applications and providing supporting documentation likely have also declined due to more open competition and technological advances.

Our analysis assumes that transaction costs are reflected in the application fees, points, mortgage insurance premiums, and other charges levied at the time of loan application or origination or are amortized in the form of a higher interest rate charged on the loan itself. Either way, total transaction costs are likely higher for credit- and/or collateral-constrained borrowers. Note also that, to the extent transaction costs have important fixed components, they may not rise proportionally with loan size, causing refinancing behavior to differ accordingly.

4. DATA

The data for this study were obtained through the Mortgage Research Group (MRG) of Jersey City, New Jersey. Until late 1996, MRG maintained a database on roughly 42 million residential properties located in thirty-six states. In addition to information pertaining to the original purchase of a property, such as date of closing, purchase price, original mortgage loan balance, and maturity and type of mortgage, data on subsequent refinancings, sales, and, in some cases, defaults, were also included.[1] In addition to the property and loan characteristics, the database also contains snapshots of the credit histories of the occupants of the properties, derived from TRW Information Services.

Aside from limiting the sample to complete observations, we further restricted it to a manageable size for computational purposes. First, we selected four clusters of counties representing some of the major regions of the country.[2] Selecting these four diverse regions assures that our statistical analysis is general rather than specific to a particular housing market. Next, we identified for each property the most recent purchase transaction, going in some cases back far as January 1984. The mortgages on many of these properties were subsequently refinanced, while the others had no further transactions recorded through the end of our sample period, December 1994, creating a zero-one, no-refinance/refinance observation. We also limited our sample to fixed-rate mortgages outstanding for a year or more, leaving the more complex decision to refinance alternative mortgage types for further study. For multiple refinancings, we considered just the first one. In addition, we excluded from the sample loans that subsequently defaulted. The resulting sample consists of 12,835 observations, of which slightly under one-third were refinanced. The credit snapshots attached to these property/loan observations are as of the second quarter of 1995.

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[1]The primary sources of this information are the records of county recorders and tax assessors.

[2]In the East, we chose four counties surrounding New York City (Orange County in New York State, and Essex, Bergen, and Monmouth Counties in New Jersey). In the South, we chose six counties in central Florida (Citrus, Clay, Escambia, Hernando, Manatee, and Marion). In the Midwest, we chose Cook County and five surrounding counties in Illinois (Dekalb, DuPage, Kane, McHenry, and Ogle). In the West, we selected Los Angeles, Ventura, and Riverside Counties in California.

5. MODEL SPECIFICATION AND VARIABLE DEFINITIONS

An Econometric Model of Prepayments

To test our hypothesis, we employ the above-mentioned loan-level data set to estimate a proportional hazard model, an approach with a long tradition in the literature. For example, Green and Shoven (1986) estimated a proportional hazard model to analyze the prepayment experience of 4000 mortgages originated by two California thrifts and concluded that the Wellenkamp decision, which weakened the enforceability of the due-on-sale clause, greatly reduced the likelihood of prepayment. In addition to quantifying the effect of the intrinsic value of refinancing on aggregate prepayments, more recent research has investigated the effect of transactions costs and various borrower and property characteristics. For example, using a proportional hazard model of mortgage terminations, Caplin, Freeman, and Tracy (1997) provide evidence that changes in home equity are directly related to the likelihood of prepayment. Archer, Ling, and McGill (1996), employing a logit specification, conclude that collateral-constrained and income-constrained borrowers are less likely to refinance their mortgage.

Our study uses Cox's proportional hazard framework to estimate a model of monthly prepayments. The implied dependent variable in hazard analysis is the duration of time until the loan is prepaid (or, inversely, the monthly rate at which the property is refinanced after duration τ, given that it has not been refinanced until that time). More specifically, the proportional hazard model is given by

$$h(\tau | x_{ti\bullet}, \beta) = h_0(\tau)\exp(x_{ti\bullet}\beta), \qquad \textbf{(3)}$$

where (τ) denotes duration of the mortgage loan and the vector $x_{ti\bullet}$ includes all explanatory variables. In the framework developed above, the duration of the i-th homeowner at month t is given by $\tau_{ti} = t - t_{0i}$. The function $h_0(\tau)$, the "baseline hazard function", represents the hazard for a household whose exogenous vector is zero.

The parameter vector β is estimated using *partial maximum likelihood* (PML), which allows us to estimate the β coefficients in the proportional hazard model without specifying a functional form for the baseline hazard. The PML estimator has good asymptotic properties in the sense that it was found to be consistent, efficient, and normally distributed (Efron 1977).

Variable Definitions

The endogenous variable in the proportional hazard model is the duration until the time of refinancing measured in months. The vector of explanatory variables $x_{ti\bullet}$ controls for the *intrinsic value* of refinancing, *the option replacement cost,* and *transaction costs*.

We measure the intrinsic value of refinancing by the present value annuity ratio proposed by Richard and Roll (1989):

$$PVALUE_{ti} = \left(\frac{r_{ci}}{r_{mti}}\right)\left(\frac{1-(1+r_{mti})^{t-T_i}}{1-(1+r_{ci})^{t-T_i}}\right), \qquad \textbf{(4)}$$

where r_{ci} again represents the coupon rate on the existing loan of the i-th borrower and r_{mti} is the current market rate or rate at which that borrower could refinance. Ignoring transaction costs, we would expect that the incentive to refinance to strengthen the more PVALUE exceeds one. As a result, the coefficient of PVALUE in the proportional hazard model is expected to be positive. In practice, borrowers may select from a menu of rate and point options, paying points in exchange for a lower coupon rate, as well as choosing from differing maturities. This creates a difficulty in comparing the coupon rate on the existing loan with the currently prevailing market rate. To deal with this, we standardized the rates by assigning r_{ci} as the average Freddie Mac commitment rate on a 30-year, fixed-rate mortgages for the month that the loan was closed.[3] This rate is for so-called A credits, or borrowers who could meet the Fannie Mae and Freddie Mac underwriting criteria. Note that this original rate is fixed for the life of the loan while the prevailing market rate on newly issued loans, r_{mti}, varies monthly. In computing $PVALUE_{ti}$, we assume that the expected holding period of the loan is 30 years. We reestimated the model using 15- and 20-year horizons and found that the proportional hazard estimates are quite robust to the choice of assumption about maturity.

In contrast to the intrinsic value of refinancing, which can be calculated directly, the option replacement cost is unobservable. We can, however, observe the standard deviation of the price of the noncallable asset. To estimate the effect of volatility on the decision to refinance, we used the implied volatility from options on 10-year U.S. Treasury note futures contracts (VOLATILITY).[4] As noted, the option replacement cost will vary positively with expected volatility, which in turn suggests a negative relationship between VOLATILITY and the proportional hazard rate.

The model controls for three of the four types of transaction costs or frictions discussed

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[3] The Freddie Mac mortgage interest rate series is published weekly. The interest rate is a contract rate with associated points and fees also published. By design, the points and fees are reasonably stable over time.

[4] The implied volatility data are from the rolling 3-month futures options contracts traded on the Chicago Board of Trade. We also experimented with several statistical variance computations or econometric projections of actual rate volatility. These alternative measures of volatility yielded qualitatively similar results. In this study we present our findings with respect to the implied volatility because this is conceptually preferable.

above. Points and fees (TC_{POINTS}) comprise an important fixed cost which vary not only with mortgage market conditions but also reflect individual borrowers' menu choice. Accordingly, we included in the set of explanatory variables the average points and fees on conventional mortgage loans closed expressed as a percent of the loan amount (POINTS), which we expect to have a negative coefficient.

Borrowers also may face additional frictions because of poor credit history (TC_{CREDIT}). In contrast to transactions costs from points and fees, which are fully observable, we cannot measure the direct cost of credit impairment. To capture this effect, we use the worst-ever credit rating from the borrower's credit snapshot (CREDIT). This credit rating represents the worst payment experience across all credit lines over the individuals entire credit history. It is expressed as the number of days late; for example, a worst-ever rating of 90 means that at one time the individual was reported ninety days late on a credit card, car loan, mortgage, or other debt. The best possible worst-ever rating is a 1, meaning no late payments ever. On the other end of the scale, a worst-ever score of 400 means that a lender has charged off a debt of that borrower.[5] Since a higher value indicates deteriorating creditworthiness, the PML coefficient of CREDIT is expected to be negative.

Another potential transaction friction stems from the amount of equity a borrower has in the property (TC_{LTV}). Borrowers applying for a mortgage loan that has a loan-to-value ratio greater than 80 percent are usually required to take out private mortgage insurance, which

[5]An alternative credit measure would have been the worst *now* credit rating or the worst payment experience as of the date of the credit snapshot. Earlier experimentation found that the effect of a bad worst ever rating on refinancing probabilities lingers even after the worst now has improved relative to worst ever. For this reason, we chose the worst ever rating.

typically involves some payment at closing as well as a higher interest rate on the loan. If the value of a property has fallen since the original purchase, in which case the loan-to-value ratio may exceed 100 percent, the borrower would most likely be unable to refinance, suggesting a negative relationship between the loan-to-value ratio and the conditional probability of refinancing. We measure the effect of home equity by the ratio of the outstanding mortgage loan balance to the current value of the property (LTV). The current value of the property is the original purchase price adjusted for local home price movements.[6]

While our analysis controls for many of the frictions associated with refinancing, it is impossible to fully account for all such frictions since they may depend on the efficiency of mortgage lenders and the level of sophistication of borrowers. A homeowner's decision about whether or not to refinance a loan may also depend on the loan size involved. To the extent certain costs of refinancings are fixed rather than proportional to the loan size, larger loans may be refinanced more readily. Thus we include a variable measuring the size of the original loan balance (SIZE), with the expectation that it should be positively correlated with refinancings, other factors equal.

Table 1 summarizes the variables used in the estimation, with separate means shown depending on whether or not the loan was refinanced.

6. STATISTICAL RESULTS

Table 2 shows the partial maximum likelihood estimates of the parameter vector β. The Wald chi-square statistics presented at the bottom of the table reject the null hypothesis that

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[6] Current home prices were estimated by adjusting the purchase price for movements in county-level home price indexes from Case, Shiller, Weiss Inc. Outstanding loan balance was inferred from the original loan amount, the contract interest rate, and the original maturity.

$H_0{:}\beta = 0$. The first column in the table presents the coefficient estimates for the entire panel. We find that the coefficient on PVALUE is positive and significant, as predicted. VOLATILITY has a significant negative effect on the refinancing decision, consistent with the hypothesized effect of interest rate uncertainty on the option replacement cost. Also as expected, POINTS have a significant negative effect. The negative and significant coefficient on LTV confirms that equity-constrained borrowers are less likely to refinance. Similarly, a high CREDIT score reduces the refinancing probability, although this effect is quantitatively less pronounced than that of LTV. The small effect of credit quality may reflect measurement problems with the worst-ever credit snapshot; if available, a continuously evolving credit measure might produce a stronger estimated effect on refinancing.[7] Finally, the size of the monthly payment (SIZE) has the predicted sign and is statistically significant, suggesting that the size of the loan may provide some incentive to refinance beyond that reflected in PVALUE and that there may be important fixed costs associated with refinancing.

Credit and Collateral Subgroups

Since earlier research has found that credit and collateral variables can interact with the other explanatory variables, we estimated the model separately for different credit and collateral subgroups. As noted previously, borrowers with LTV ratios greater than 80 percent would typically have to incur additional private mortgage insurance costs. This key threshold in LTV

[7] For example, the delinquency may have occurred some time ago, been on a less significant credit line (for instance, a store card rather than a mortgage), or the borrower may have been able to provide a reasonable explanation for the delinquency. Also, Peristiani, Bennett, Monsen, Peach, and Raiff (1997) report evidence that an improvement in credit history (worst now better than worst ever) increases refinancing probabilities, but not enough to completely erase the effect of a poor worst-ever score.

allows us to convert the time-dependent ratio into a qualitative explanatory variable. The findings, shown in Table 2, Columns 2 through 5, are again consistent with the notion that credit and equity affect refinancing probability, but a channel of effect is clarified: The estimated sensitivity of refinancing probability to PVALUE is appreciably lower for credit- and equity-constrained borrowers. This is consistent with the separate findings of interaction effects between refinancing incentives and home equity (Caplin, Freeman, and Tracy 1997) and between refinancing incentives and credit ratings.

Although all explanatory variables in the model have a statistically significant effect on the conditional probability of prepayment, their economic significance is obscured by the nonlinear nature of the proportional hazard model. The impact of a poor credit rating can be illustrated by estimating the survival function of loans, that is, the cumulative likelihood of a loan "surviving" (i.e., not being refinanced) over time, for borrowers in different CREDIT categories. In the partial likelihood framework, the survival function can be estimated from the semi-parametric estimator

$$S(\tau, x_{ti\bullet}) = (S_0(\tau))^{\exp(x_{ti\bullet}\beta)}. \qquad \textbf{(5)}$$

The variable $S_0(\tau)$ represents the baseline survival function. An estimate of the baseline function is obtained using a nonparametric maximum likelihood method. Figure 3 presents survival functions for two CREDIT categories, good credits (worst ever rating equal to 1; the bottom line) and poor credits (worst ever rating equal to 400; the top line). These estimated survival functions indicate that--under the market conditions faced by the borrowers in our sample--nearly 13 percent of the good credits had refinanced after 100 months (eight years and 4 months) versus just about 3 percent of the poor credits.[8] In a similar fashion, Figure 4 presents the survival experience for collateral-constrained borrowers. The bottom survival curve depicts the refinancing experience of homeowners whose average LTV ratio was less than 80 percent, while the top curve represents the survival of collateral-constrained individuals. This graphical comparison underscores the economic significance of home equity. While only 5 percent of collateral-constrained borrowers were able to refinance after 100 months of the life of the loan, during the same time framework close to 46 percent of the unconstrained sample refinanced their mortgage. These findings underline the need to properly control for these factors, which enter the equations in nonlinear ways, in comparing refinancing propensities over time.

Comparing Refinancing Propensities in the 1980s and 1990s

To explore the possibility that refinancing behavior has changed, we divided the sample between mortgagors that purchased their homes during 1984-90 and those who purchased during 1991-94. Because the sample includes just one credit snapshot (1995Q2), we were hesitant to assign that credit information to refinancing behavior over the period of a decade. Nevertheless, based on the Table 2 results, credit is demonstrably important and should not be ignored in intertemporal comparisons. Therefore, in this sample splitting exercise we controlled for credit rating by limiting our sample to good credits (those with a worst ever rating of 1). By taking this approach, we arguably reduce the generality of our results somewhat, since an increase in the incidence of weak credit ratings in the 1990s would be at least a partial offset to any increased propensity to refinance among good credits. On the other hand, limiting the sample to good

[8] It is important to remember that refinancing probabilities are considerably smaller than overall prepayment probabilities, which include sales and defaults. Thus, the survival rates in this sample (which excludes sales and defaults) will appear correspondingly higher.

credits makes ours a purer test of the hypothesis that structural changes have increased refinancing probabilities.

The proportional hazard model, excluding the credit rating variable, is estimated for the two subsamples to test the null hypothesis H_0: $\beta_{84\text{-}90}=\beta_{91\text{-}94}$, where the subscripts identify the date range of home purchases in the respective subsamples. The coefficient estimates for $\beta_{91\text{-}94}$ are shown in column 3 of Table 3. Estimating the model for borrowers that took out a loan during 1984-90 is not completely straightforward because in this case the sample "spills over" into the 1990s (that is, purchasers in the 1980s are still at risk of refinancing their purchased mortgages in the latter decade). To address this issue, the proportional hazard coefficients presented in the column 1 of Table 3 represent early period purchases (1984-90) but with the data truncated after 1990 -- focusing the estimation more closely on refinancing behavior during 1984-90. For comparison, column 2 shows the coefficient estimates for borrowers in 1984-90, but continuing the sample into the 1990s.[9]

The differences in most estimated coefficients for the subperiods are quite large and statistically significant. As the Wald statistics show (bottom of Table 3), borrowers in the 1990s exhibit a much greater willingness to refinance. Households that purchased during 1991-94 (column 3) are much more responsive to the intrinsic value of refinancing (PVALUE). In particular, the coefficients of POINTS and LTV have the predicted sign and are statistically

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[9]Alternatively, one can use dummy regressors to test the hypothesis that the refinancing behavior has changed in the two subperiods. Again, we can employ two dummy explanatory variables to denote homeowners who purchased and refinanced their homes during 1991-94, or purchased their homes during 1984-90 but refinanced in the 1990s. These dummy variables can be interacted with other explanatory variables in the model to measure structural change. As expected, the statistical results from these two alternative methods of estimation are quite similar.

significant. The effect of VOLATILITY is negative and highly significant, suggesting that the likelihood of refinancing in the 1990s was lower if interest rates were anticipated to be more volatile in the future. By contrast, with the exception of points and fees, the probability of prepayment during 1984-90 (first column of Table 3) is not particularly influenced by any of the remaining economic factors. This large differences in sensitivity to PVALUE and LTV in the two subperiods are quite surprising given that, on average, mortgagors faced less favorable interest rate and collateral conditions over the 1991-94 period.[10]

One could attribute the weak response by borrowers in the 1980s to the way the sample is prematurely truncated after 1990. In the early part of the life of a mortgage loan, homeowners are typically constrained by the fixed costs of refinancing and may be unable to react to favorable interest rate conditions. In the housing finance terminology, a new loan (or newly-issued pool of mortgages) is not seasoned. While it is true that by truncating the sample after 1990 some of the purchases in the 1980s are not allowed to season, we should point out that we also truncated in a similar way the spell for purchasers in the 1990s after 1994. In fact, the average duration for mortgage loans purchased in the 1990s is 23 months. In contrast, the average duration for loans purchased during the 1980s is 32 months. Thus, even though mortgage loans in the 1990s were on average less seasoned, the prepayment experience of these loans was significantly higher. Looking at the hazard model for purchases during the 1980s over the complete spell 1984-94 (second column of Table 3), we observe that borrowers are somewhat more responsive to interest

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[10]Overall, mortgage holders in our sample enjoyed a more favorable interest rate environment during 1984-1990. The average PVALUE ratio during the period 1991-94 was around 0.99 compared to 1.03 during 1984-90. Moreover, the average loan-to-value ratio in the earlier period was close to 60 percent compared to 70 percent during 1991-94.

rate differentials, interest rate volatility, and collateral. Nonetheless, as the chi-square test given at the bottom of the table suggests, individuals that acquired a home during the 1990s continued to exhibit a significantly higher propensity to refinance.

Also supportive of this hypothesis is the fact that the size of the coefficient on the variable SIZE declines very sharply in the latter period, consistent with the idea that fixed-cost transaction frictions have declined over time. In short, the results are quite consistent with the idea that lower transactions costs (measurable and otherwise), and perhaps increased sophistication of borrowers, have increased the propensity to refinance. These findings offer strong support for our hypothesis of a structural change and are consistent with the anecdotal conclusion that the interest rate differential needed to induce a mortgagor to refinance has declined.

Figure 5 contrasts the mortgage loan survival experience of the 1990s with that of the 1980s. For the 1980s, we simulate the survival function two ways. The top curve represents 1984 to 1990 parameter estimates (column 1 of Table 3) with values of the explanatory variables for the same period.[11] The middle curve represents again the 1984-90 estimated hazard model but now simulated using the explanatory variables from the 1991-94 period. The distance between the top and middle survival functions reflects the effects of the differing exogenous variables (including, importantly, about a 50 basis point difference in average points and fees) between the two periods.

The bottom survival curve represents the 1991-94 hazard model (given in the third

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[11] The survival function for the untruncated 1980s sample (column 2 of Table 3) is very similar.

column of Table 3) simulated with the 1991-94 values of the explanatory variables. Hence the middle and bottom survival curves compare individuals exposed to the same explanatory variables, but with different responses to those conditions as represented by the differences in the estimated coefficients. The distance between these two curves represents the difference in refinancing behavior that can be attributed to structural change in the mortgage market, above and beyond the changes in measurable transaction frictions such as points and fees. As seen from the figure, after four years in the 1990's, nearly 14 percent of the purchase mortgages loans had been refinanced. In contrast, under 1980s behavioral response, cumulative refinancings over the first four years would have totaled only 9 percent.

7. CONCLUSIONS

We developed an empirical model to test whether structural changes in the U.S. mortgage market have affected mortgagors' refinancing behavior. We hypothesized that the intrinsic benefit required to trigger a refinancing has become smaller, due to a combination of technological, regulatory, and structural changes that have made mortgage origination more competitive and more efficient. To test this hypothesis, we estimated an empirical hazard model of loan survival for two time subperiods, using a database that allowed us to carefully control for homeowners' credit ratings, equity, loan size, and measurable transaction costs. Overall, we are confident that our hypothesis has been tested on the basis of a reasonably comprehensive model of individual and market determinants of refinancings.

Our findings strongly confirm earlier findings that credit ratings and home equity have significant effects on refinancing probability. In addition, we provide evidence that homeowners postpone refinancing in the face of increased interest rate volatility, consistent with option value theory. Finally, our results clearly support the hypothesis that structural change in the mortgage market has increased homeowners' propensity to refinancing. This conclusion emerges from two findings. One is that measurable transaction costs, such as points and fees and other fixed costs, are quite important in the refinancing decision and that those costs have declined significantly in the 1990s relative to 1980s--a development we attribute to increased efficiency and competition in mortgage origination. Secondly, even after controlling for points and fees, loan size, and other important variables, refinancing probabilities were considerably higher in the latter period. This we attribute to declines in nonmeasurable frictions, which likely takes the form of aggressive solicitations of refinancings by lenders, which have the effect of disseminating information faster and more broadly, as well as increased financial sophistication among homeowners.

REFERENCES

Archer, Wayne, David Ling, and Gary McGill. "The Effect of Income and Collateral Constraints on Residential Mortgage Terminations," *Regional Science and Urban Economics* 26 (1996), 235-61.

Caplin, Andrew, Charles Freeman, and Joseph Tracy. "Collateral Damage: How Refinancing Constraints Exacerbate Regional Recessions," *Journal of Money, Credit, and Banking* 29 (November 1997), 496-516.

Efron, B. "The Efficiency of Cox's Likelihood Function for Censored Data," *Journal of the American Statistical Association* 72 (1977), 557-65.

Follain, James R., James O. Scott, TL Tyler Yang. "Microfoundations of a Mortgage Prepayment Function," *Journal of Real Estate and Economics* 5 (1992), 197-217.

Giliberto, Michael S. and Thomas G. Thibodeau. "Modeling Conventional Residential Mortgage

Refinancings," *Journal of Real Estate Finance and Economics* 2 (1989), 285-99.

Glaesar, Edward R. and Hedi D. Kallal. "Thin Markets, Asymmetric Information, and Mortgage Backed Securities," *Journal of Financial Intermediation* 6 (1997), 64-86.

Green, Jerry and John B. Shoven. "The Effects of Interest Rates on Mortgage Prepayments," *Journal of Money, Credit, and Banking* 18 (1986), 41-59.

Hendershott, Patric H. (1992) "The Market for Home Mortgage Credit: Recent Changes and Future Prospects" in *The Changing Market in Financial Services*, Proceedings of the Fifteenth Annual Economic Policy Conference of the Federal Reserve Bank of St. Louis, Kluwer Academic Publishers. 99-123.

Hull, John C. *Options, Futures, and Other Derivative Securities*. Englewood Cliffs, New Jersey: Prentice-Hall, 1993.

Lekkas, Vassilis. "Comparing Refinance Booms," *Secondary Mortgage Market* 10 (Winter 1993), 15-18.

Peristiani, Stavros, Paul Bennett, Gordon Monsen, Richard Peach, and Jonathan Raiff. "Credit, Equity, and Mortgage Refinancings," *Federal Reserve Bank of New York Economic Policy Review* 3 (July 1997), 83-99.

Richard, Scott F., and Richard Roll. "Prepayments on Fixed-Rate Mortgage-backed Securities," *The Journal of Portfolio Management* 15 (Spring 1989), 73-82.

TABLE 1
SUMMARY STATISTICS

Variables	Description	Mean Refinancing	 No Refinancing
DURATION	Age of loan (measured in months).	48.17	53.59
PVALUE	Present value ratio as defined by equation (6) (percent)	117	111
LTV	Current loan-to-value (percent).	54.94	66.49
VOLATILITY	Implied volatility on options on the 10-year treasury note futures (basis points).	6.63	7.06
POINTS	Initial fees and point changes on conventional home mortgages. National average for all major lenders (percent).	1.99	2.03
CREDIT	Worst delinquency ever (1 = good credit, 30, 60, 90, 120, 150, 180, 400=default).	64.79	99.71
SIZE	Logarithm of original loan balance (balance measured in thousands of dollars).	11.65	11.39
Number of monthly observations		4226	497243

TABLE 2
FACTORS INFLUENCING THE DECISION TO REFINANCE: PROPORTIONAL HAZARD MODEL

Explanatory Variable	All Borrowers	Good Credit (WRSTEVER=1)		Poor Credit (WRSTEVER=400)	
		LTV≤80	LTV>80	LTV≤80	LTV>80
DUM-NY	0.688***	0.966***	0.511***	0.747***	0.112
	(157.97)	(130.41)	(7.85)	(12.49)	(0.12)
DUM-IL	-0.947***	-0.435***	0.258	-1.81***	-1.862***
	(194.96)	(21.52)	(1.23)	(56.97)	(12.67)
DUM-FL	0.959***	1.076***	1.307***	1.175***	1.003***
	(292.70)	(152.97)	(45.10)	(37.55)	(8.05)
WRSTEVER	-0.001***				
	(65.39)				
PVALUE	1.210***	1.403***	1.463***	-2.388***	-1.957**
	(40.07)	(22.70)	(6.84)	(13.18)	(4.32)
VOLATILITY	-0.454***	-0.455***	-0.532***	-0.317***	-0.651***
	(371.26)	(161.53)	(75.50)	(13.53)	(35.65)
LTV	-0.019***	-0.021***	0.010*	-0.037***	0.015
	(763.55)	(327.45)	(2.65)	(163.16)	(2.00)
POINTS	-5.350***	-5.836***	-3.915***	-4.91***	-3.166***
	(2462)	(1261)	(165.25)	(179.49)	(37.61)
SIZE	0.326***	0.271***	0.740***	0.146	0.788***
	(130.66)	(43.27)	(71.07)	(2.01)	(20.30)
Wald chi-square	6284.80	2987.14	379.55	730.45	155.43
Censored obs.	497243	166484	83552	54369	50339
Refinancing obs.	4226	1864	637	332	205

NOTES: The symbols (***), (**), and (*) indicate statistical significance at the 1-, 5-, and 10-percent level, respectively. Table 1 describes in more detail the explanatory variables.

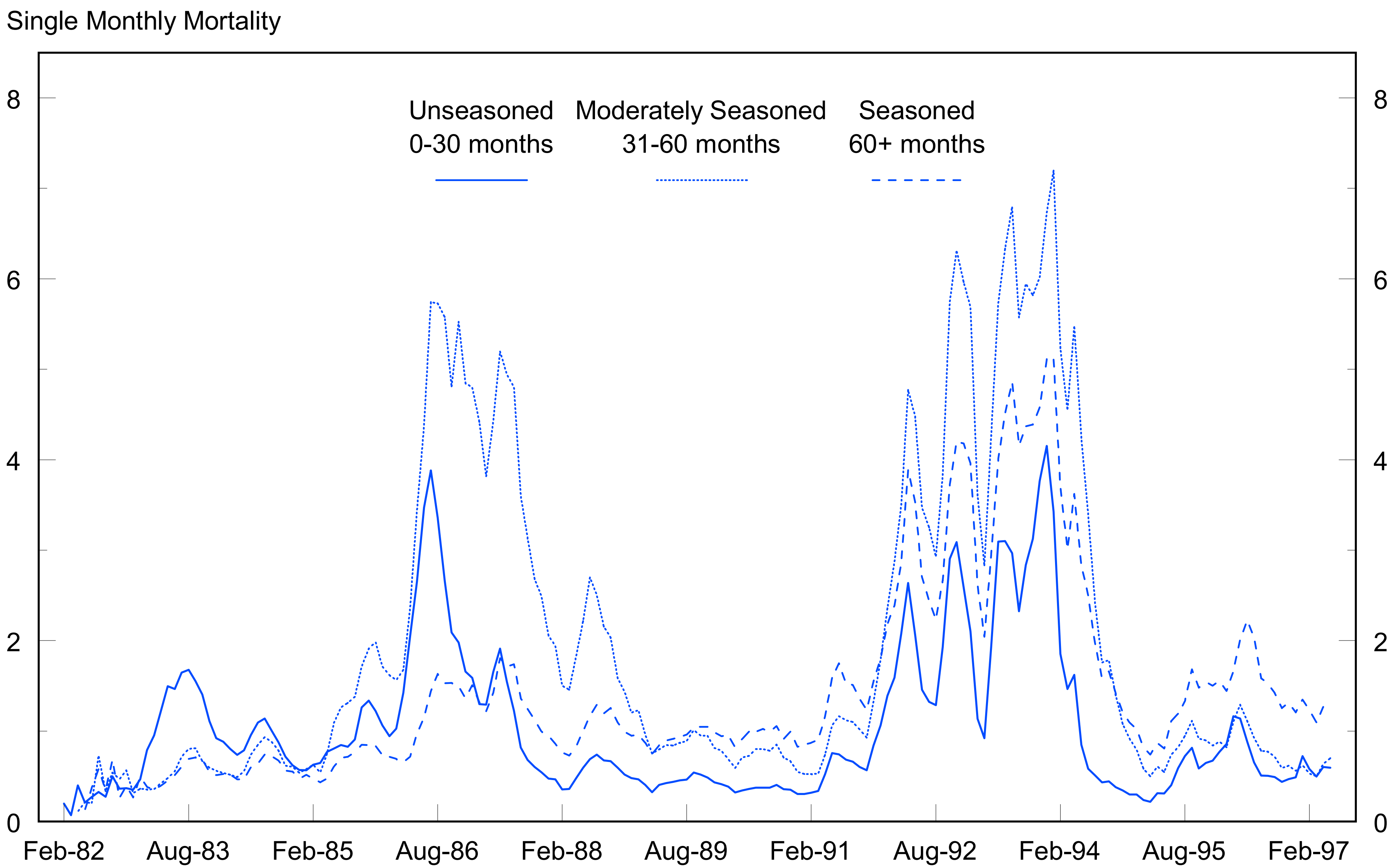
TABLE 3
THE WILLINGNESS TO REFINANCE DURING THE 1980s AND 1990s
(Numbers in parentheses represent Wald chi-square statistics).

	Purchases in 1984 -1990		Purchases in 1991-1994
Variable	1984-1990[a]	1984-1994[b]	
DUM-NY	-17.91 (0.00)	1.448*** (261.38)	-0.849*** (47.12)
DUM-IL	-2.129*** (56.06)	-0.777*** (51.17)	0.060 (0.18)
DUM-FL	-0.436** (5.02)	1.388*** (252.50)	-0.441*** (10.05)
PVALUE	-1.79* (2.34)	0.832*** (6.86)	3.76*** (44.23)
LTV	0.033*** (41.88)	-0.008*** (43.38)	-0.031*** (544.91)
VOLATILITY	0.087 (1.23)	-0.391*** (101.29)	-0.623*** (141.43)
POINTS	-3.430*** (48.87)	-3.89*** (405.78)	-5.118*** (305.05)
SIZE	0.536*** (24.03)	0.413*** (76.81)	0.052 (0.75)
χ^2 test H_0:$\beta=0$	235.80***	1686.68***	1317.95***
χ^2 test H_0:$\beta_{91-94}=\beta_{84-90}$	297.85***	319.74***	
Refinancing obs.	277	1486	1015
Censored obs.	97520	160095	89941

[a]Sample of homeowners is truncated after 1990.
[b]Proportional hazard estimates for the complete spell (e.g., last observation of panel ends in December 1994 or at the month of refinancing, which ever comes first).

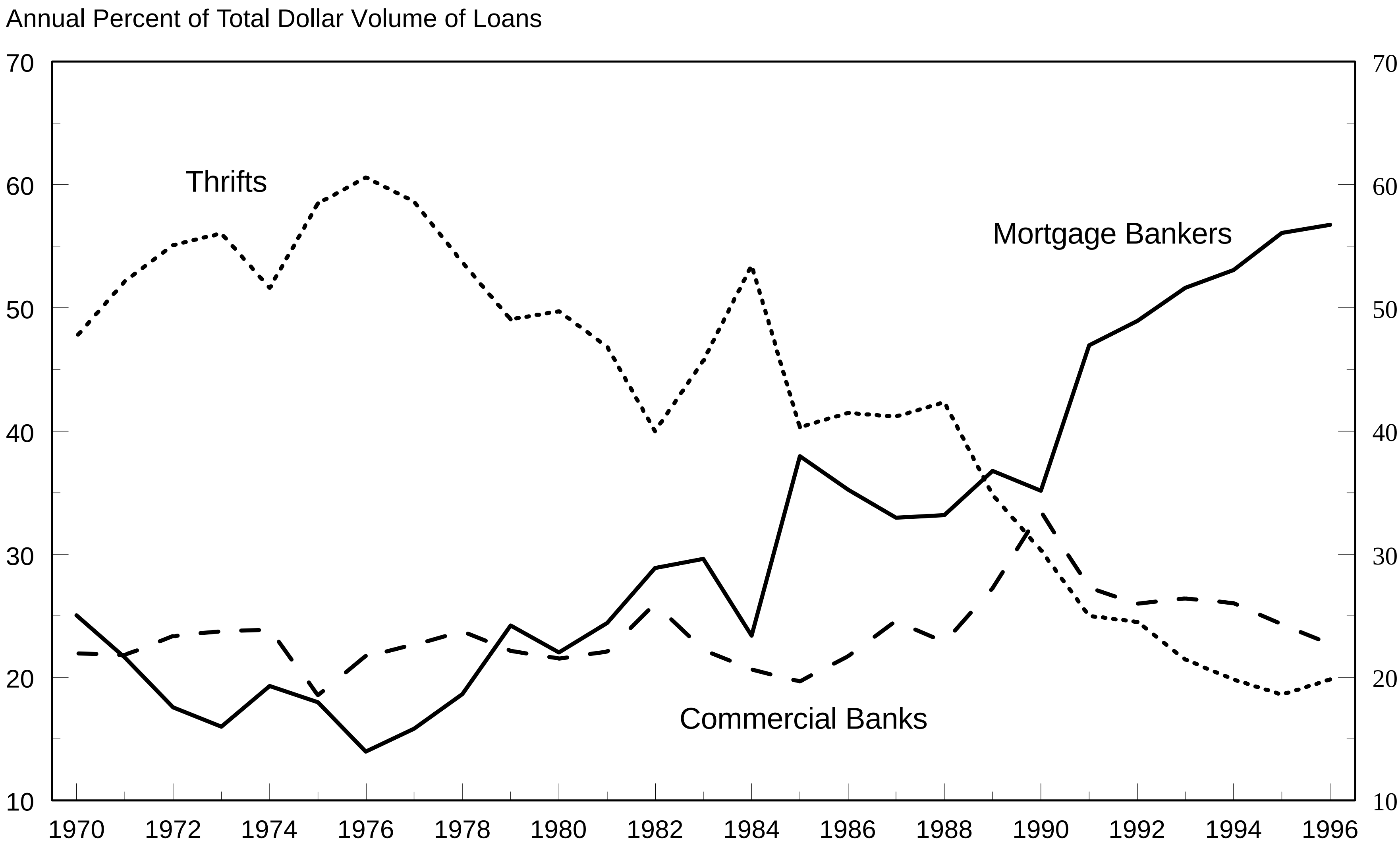
NOTES: The symbols (***), (**), and (*) indicate statistical significance at the 1-, 5-, and 10-percent level, respectively. Table 1 describes in more detail the explanatory variables. χ^2 values are Wald statistics.

Figure 1: Prepayment Speeds on FNMA MBS Backed by 30-year Fixed Rate Mortgages



Source: Global Advanced Technology Corporation

Figure 2: Primary Mortgage Market: Market Shares by Type of Lender
(Percent of 1-4 Family Originations)



Source: U.S. Department of Housing and Urban Development, *Survey of Mortgage Lending Activity*

Figure 3. Survival Function by Credit Level

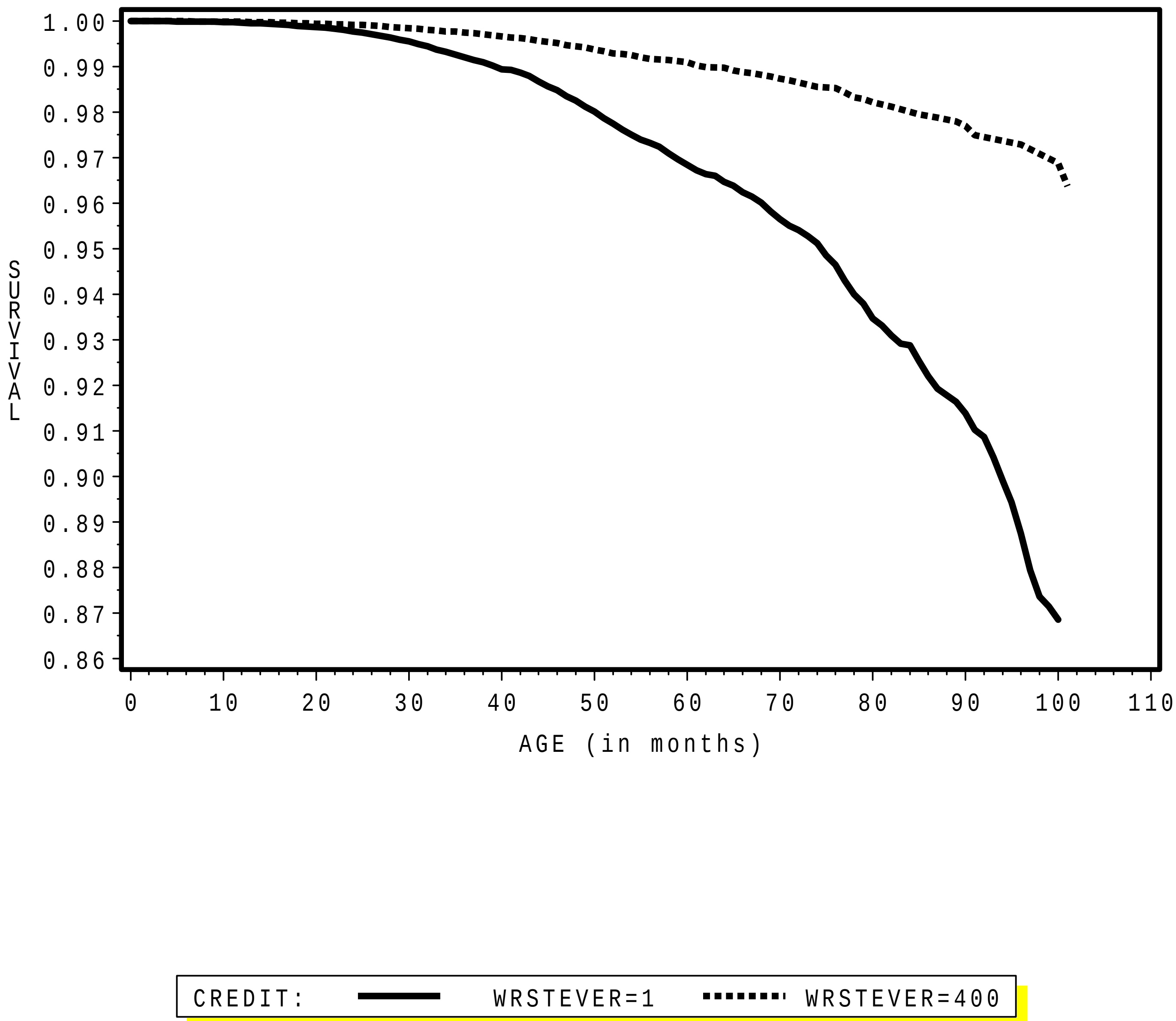


Figure 4. The Survival Function by LTV Level

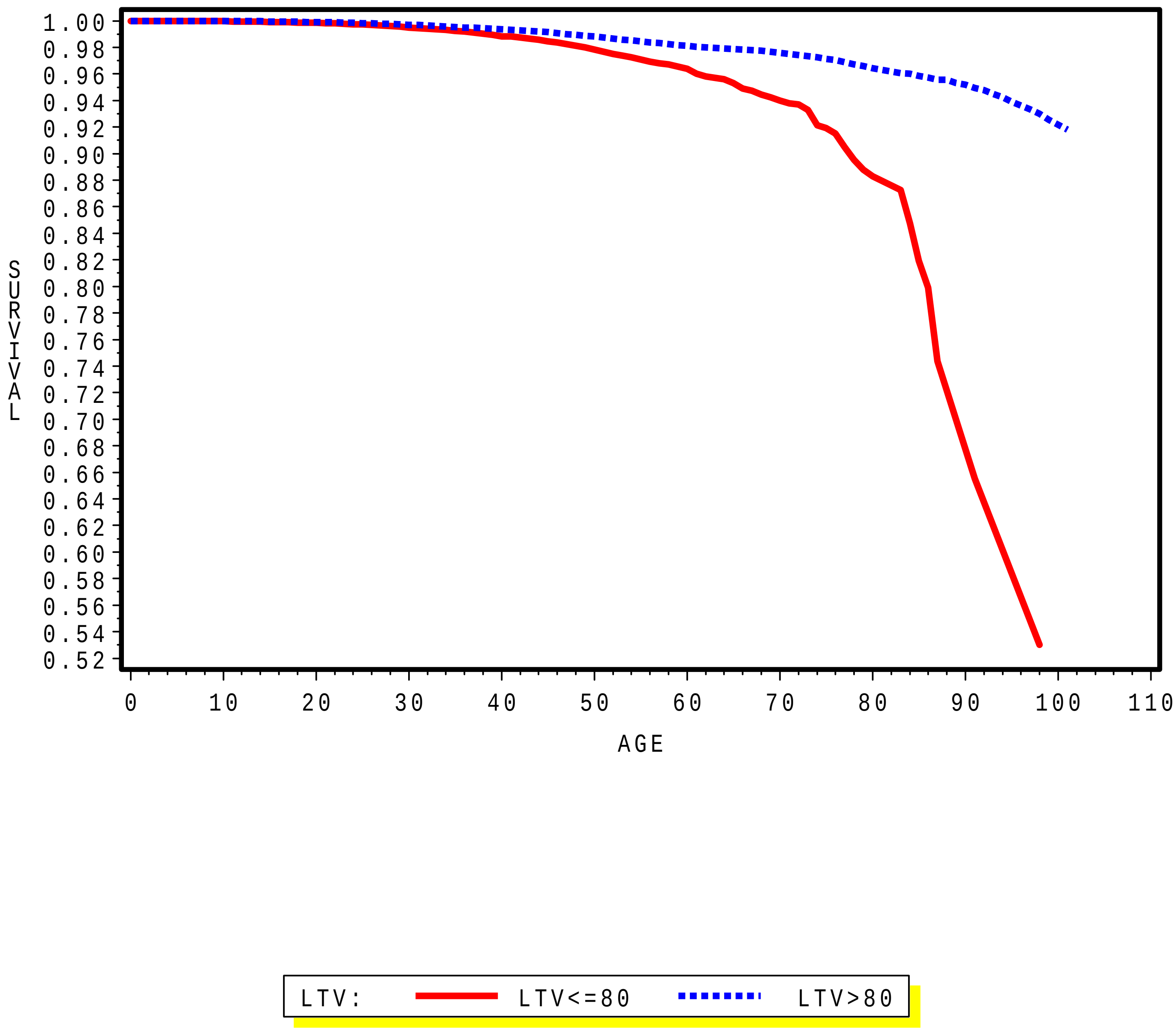


Figure 5. Survival Functions Before and After 1990