THE JOURNAL OF FINANCE • VOL. XLV, NO. 5 • DECEMBER 1990

# The Relative Termination Experience of Adjustable to Fixed-Rate Mortgages

DONALD F. CUNNINGHAM and CHARLES A. CAPONE, JR.*

**ABSTRACT**

Our study uses a multinomial logit model to analyze the concurrent termination experience of adjustable-rate and fixed-rate mortgages. A new set of ARM-specific interactive determinants expands the conventional FRM specification to isolate the unique termination behavior of ARMs. We find that expected rate adjustments and large lifetime caps are positively related to ARM termination probabilities while long adjustment frequencies are inversely related. Caps, both periodic and lifetime, have a secondary, inverse effect on termination probabilities when interest-rate movements exceed cap limits. The model also shows that interest-rate expectations affect FRM terminations more strongly than ARM terminations.

IN SEPTEMBER 1981 COMMITMENT RATES on fixed-rate mortgages (FRMs) peaked at 18% after a 3 year, 850 basis point rise. Lenders, encumbered with losses from devalued FRM portfolios, faced insolvency, while mortgage applicants, constrained by large payment burdens, contended with disqualification.[1] Adjustable-rate mortgages (ARMs) emerged as a solution to both problems. The adjusting note rate allowed lenders to hedge their portfolios against rising interest rates, and the discounting of initial ARM rates kept household payment ratios within underwriting guidelines.

The benefit of ARMs remains questionable, however, because of the uncertainty surrounding their future payment streams. In particular, the shift of interest rate risk to borrowers may result in higher default and prepayment risks to lenders. Uncertainty is further compounded by nonstandard contracts for buydown terms, period caps, life caps, indexes, and adjustment periods.

Originators and insurers of ARMs, as well as investors in the emerging market for ARM-backed securities, need ARM-specific methods for evaluating the cash-flow risks of these unique instruments. In this paper, we address these issues by examining the concurrent default and prepayment experience of ARMs

* Department of Finance and Department of Economics, respectively, Baylor University, Waco, Texas. This research was sponsored and funded by the Federal Home Loan Mortgage Corporation (FHLMC) in cooperation with North American Mortgage Company (NAMC) of Houston, Texas, which provided the data for this study. The views and conclusions expressed herein are those of the authors and do not necessarily reflect the views of past or present employees or officers of the FHLMC or NAMC. The authors wish to express their appreciation to Michael Lea, J. T. Rose, Kerry Vandell, Peter Zorn, and an anonymous referee for their helpful comments.

[1] The National Association of Realtors reported the house affordability index fell by 36% during this period.

and FRMs from a disaggregate data set of mortgage loan files.[2] Termination probabilities are estimated with a multinomial logit model using ARM-specific (interactive) variables to capture the difference in ARM and FRM termination behavior.

The literature on FRM default is well developed while research on prepayment experience is more recent.[3] With the exception of Vandell and Thibodeau (1985) and Gau (1978), these studies are based on aggregate data. They also encompass time periods that precede the volatile interest rate environment of the early 1980s.

Several studies simulate ARM default, but none relate the termination experience of ARMs to contemporaneous microeconomic variables.[4] Sa-Aadu (1988) used only variables observed at the time of origination to analyze ARM defaults but did not address prepayments. Lea and Zorn (1986) used data from Canada to relate the termination experience of rollover mortgages to macro-level variable changes. However, without the equivalent of American FRMs, no comparisons can be drawn between ARMs and FRMs.

The mortgages sampled in this study originated in Texas, predominantly Houston, and terminated during the region's mid-1982 to 1985 period of adverse economic conditions. During this period, mortgage interest rates fell from 16.75% (July 1982) to 13% (June 1983), rose again to 14.75% (July 1984), and then declined steadily to 11.00% by the end of 1985. Regional house prices were equally volatile, rising through the second quarter of 1983 and then declining through the fourth quarter of 1985. In addition to these full cyclical swings, the data is further enriched by a choice-based sampling procedure that supplies a large proportion of defaulted and prepaid loans.[5]

Our analysis and findings are presented in the following order: the theoretical model is reviewed in Section I, the data is summarized in Section II, and the estimation results are discused in Section III. A brief simulation of the estimated equation is presented in Section IV with concluding remarks in Section V.

## I. Modeling Mortgage Termination

Default models traditionally formulate explanatory variables on the basis of underwriting guidelines set forth by the secondary-market agencies. The loan-to-value ratio (LTV) and payment-to-income ratio (PTY), in particular, are cornerstone determinants. Other variables are generally categorized as mortgage

[2] Variable measurement is based on individual loan observations (disaggregate) rather than cohort averages (aggregate) of mortgage data (Campbell and Dietrich 1983; Peters, Pinkus, and Askin 1984; Von Furstenberg 1969).

[3] See Swan (1982) for a review of the default literature. Studies of prepayment include Campbell and Dietrich (1983), Peters, Pinkus, and Askin (1984), Foster and Van Order (1985), and Green and Shoven (1986).

[4] See Field and Cassidy (1977), Vandell (1978), and Webb (1982).

[5] Choice-based sampling permits the study of low probability events without requiring excessively large data pools. The low probability events are included in the choice-based sample in substantially greater proportions than those observed in the universe. Our sample contains roughly one-third defaulted loans, even though defaults typically average less than 1% in large mortgage portfolios.

related, property related, borrower related, or macroeconomic. Campbell and Dietrich (1983) investigated prepayment as well as default, and they documented the explanatory power of the traditional variables over time by adjusting for macro-level changes in prices and incomes.

Table I summarizes the variables found significant in previous studies. Without exception, the LTV ratio is a strong positive indicator of default risk, while results for the PTY ratio and unemployment rate are less consistent.[6] Option-based models used to price mortgage default risk (Cunningham and Hendershott (1984) and Epperson, Kau, Keenan, and Muller (1985)) provide a rational theory of mortgage default that supports the dominating influence of equity LTV and questions the relevance of payment ratios and unemployment rates.[7] Current equity, when positive, induces the repayment incentives of a call option on the house (remain current or prepay); when negative, it induces the repayment incentives of a put option (default). Even if unemployment rates increase, resulting in lost jobs and increased PTY ratios, borrowers should not default if positive equity can be recovered by selling the property.[8]

We follow the logic of the option-based approach by interpreting the variables in a traditional specification as proxies for option positions in the house and mortgage. Thus, property and mortgage characteristics are critical because of their impact on borrowers' equity, and the current level of mortgage rates is equally important because of its inverse relationship to mortgage value.[9] Borrower characteristics, in contrast, should generate less robust results. Although they are proxies for moving costs if borrowers are contemplating default or prepayment induced by a move, they become irrelevant if refinancing is being considered because moving costs are zero.

Within this framework, we model a wealth-maximizing household's probability of choosing repayment alternative $i$, $P_n(i)$, given a vector of borrower, mortgage, house, and macroeconomic variables, $Z_n$, with the multinomial logit specification:

$$P_n(i \mid Z_n) = \frac{e^{\beta_i' Z_n}}{\sum_i e^{\beta_i' Z_n}} \tag{1}$$

where:

$i$ = current, default, prepay
$\beta_i$ = vector of utility weights for choice $i$
$n$ = household index.

[6] Campbell and Dietrich (1983) pointed out that the current LTV (at time of observation) captured the default option effect while the initial LTV reflected underwriting standards.

[7] Jackson and Kaserman (1980) presented a nonoption-based discussion of the equity versus ability-to-pay hypotheses of mortgage default.

[8] Foster and Van Order (1984, 1985) explored this rational response hypothesis and found that a simple specification of homeowner's equity works rather well in explaining default if simulated transactions costs are also included. These costs can be significant as shown by Vandell and Thibodeau (1985) and Sa-Aadu (1988).

[9] A distinction is made between mortgage balance, which is static except for amortization, and mortgage value, which fluctuates inversely to interest rate movements. However, unlike a noncallable fixed-income security, mortgage value is borrower-specific because its term-to-maturity is set by the borrower's choice to move or refinance.

**Table I**

## Summary of Significant Variables in Previous Termination Studies

Entries are the hypothesized and actual signs for statistically significant regression variables investigated in previous studies of mortgage termination. Prepayment signs appear in parentheses. The precise specification of the regression variables varied with each study.

| | Expected Sign | | FRM Studies | | | | | | ARM Studies | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Von Furstenberg (1969) | Campbell, Dietrich (1983) | | Peters, Pinkus, Askin (1984) | | Vandell, Thibodeau (1985) | Lea, Zorn (1986) | | Sa-Aadu (1988) |
| Variable | Default | Prepay | Default | Default | Prepay | Default | Prepay | Default | Default | Prepay | Default |
| Mortgage Characteristics: | | | | | | | | | | | |
| CHANGE = magnitude of change in note rate | + | (+) | | | | | | | * | (+) | |
| FOA = frequency of rate adjustment | − | na[a] | | | | | | | | | − |
| MAGE = mortgage age | + | (+) | + | + | (+) | | (+) | * | | | + |
| MAGESQ = mortgage age squared | − | (−) | − | − | (−) | | (−) | * | | | |
| SPREAD = current mortgage rate relative to note rate | − | (−) | | − | (−) | | (−) | − | − | (−) | |
| Property Characteristics: | | | | | | | | | | | |
| HAGE = age of house | + | (+) | | + | (−) | | | | | | + |
| LTV = the ratio of principal balance to house value | + | (−) | + | + | (−) | | (+) | + | | | + |
| NBHGOOD = quality of neighborhood or property | − | na | | | | | | − | | | − |
| REALH = real price of housing | − | (+) | | | | | | | * | (−) | |

**Table I—*Continued***

| | Expected Sign | | FRM Studies | | | | | | ARM Studies | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Von Furstenberg (1969) | Campbell, Dietrich (1983) | | Peters, Pinkus, Askin (1984) | | Vandell, Thibodeau (1985) | Lea, Zorn (1986) | | Sa-Aadu (1988) |
| Variable | Default | Prepay | Default | Default | Prepay | Default | Prepay | Default | Default | Prepay | Default |
| Borrower Characteristics: | | | | | | | | | | | |
| BAGE = borrower's age in years at time of observation | – | (–) | | | | | (–) | | | | |
| COBORRINVINC = investment income from co-borrower used as qualifying income | – | na | | | | | | + | | | |
| COMMINC = commissions as source of borrower income | + | na | | | | | | + | | | * |
| PTY = ratio of mortgage payment to borrower income | + | (–) | | + | (+) | + | (–) | – | | | * |
| NETWORTH = net worth of borrower | – | (+) | | | | | (+) | – | | | * |
| SELFEMPL = dummy variable of one if self-employed | + | na | | | | | | + | | | |
| YRSCW = years employed in current line of work | – | na | | | | – | | – | | | – |
| Macro Economic Conditions: | | | | | | | | | | | |
| CREDIT = net change in consumer credit outstanding | + | na | | | | + | | | | | |
| GNP = current measure of gross national product | – | (+) | | | | – | (+) | | | | |
| MIGRN = net regional migration per thousand of population | – | (+) | | | | – | (+) | | | | |
| REALY = real income | – | (+) | | | | | | | – | * | |
| UNEM = current rate of unemployment | + | (–) | | + | (–) | | | * | + | * | |

[a] na: variable not tested for prepayment effect.
* Insignificant results.

The $\beta_i$ parameters are utility weights because estimates of wealth-maximizing choices are indirect measures of the household's attempt to maximize utility. The variables $Z_n$ are proxies for state variables: option positions in the house or mortgage, costs of exercising the option, and general economic conditions. These are listed and described in Table II with summary statistics.

Given the thorough treatment of default and prepayment determinants cited in the literature in Table I, we limit our discussion primarily to the new ARM-specific category of variables. These are interactive terms used to capture the difference between ARM and FRM termination behavior. All property, mortgage, and economic variables are current as of the observation date, and the ARM note rate reflects all periodic adjustments.[10]

Three provisions in the ARM contract determine the degree of interest rate risk shifted from lender to borrower: the interest-rate-adjustment frequency (AFREQ), lifetime caps on the total interest-rate change (LCAP), and period caps on the allowable interest rate change at each adjustment date. AFREQ and LCAP are directly specified in the model;[11] period caps are indirectly specified through an expected adjustment variable (EXPADJ). Long adjustment frequencies (AFREQ) insulate ARM borrowers from frequent changes in their payment obligations and should result in lower default and prepayment probabilities. Large LCAPs expose borrowers to greater interest rate risk and are hypothesized to result in higher probabilities of default and prepayment. Period caps set the maximum interest rate adjustment that borrowers can expect to incur on the adjustment date. A proxy for the borrower's expected rate adjustment (EXPADJ) is created by taking the minimum of the difference between the current market rate and the current note rate (SPREAD) term and the period cap, which should be a direct influence on default and prepayment probabilities.[12]

Between adjustment dates, ARM borrowers anticipate what EXPADJ will be on the next adjustment date before deciding whether or not to terminate currently. For example, the incentive to terminate an ARM as a result of a positive EXPADJ is mitigated if interest rates are expected to fall by the next adjustment date. We construct the yield-curve variable YLDCURV as a proxy for borrowers' interest rate expectations. Chen and Ling (1989) demonstrated a positive relationship between YLDCURV and FRM terminations.[13] Whether ARM borrowers react as strongly to interest rate expectations as FRM borrowers is tested with an interaction term between ARMs and YLDCURV (ARMYLDCURV).

A secondary and negative effect of lifetime and period caps on termination is hypothesized to occur when cap limits are exceeded by interest rate movements.

[10] The current ARM note rate and ARM payment were collected from copies of adjustment notices mailed to borrowers.

[11] LCAP and EXPADJ are expressed as percentages of the current note rate to prevent any nonlinear effects. A 5% lifetime cap, for example, on a 15% current ARM note rate results in an LCAP variable value of 33%.

[12] Period caps are also not measured directly because they are virtually perfectly correlated with life caps.

[13] Refinancing is postponed if the yield curve is steeply negative because waiting should reward borrowers with even lower rates. Conversely, a steeply positive yield curve would encourage quick termination (as a result of moving, for example) in order to avoid higher financing costs as a result of waiting.

Caps exceeded by positive interest rate changes become valuable call options on below-market financing, delaying default and prepayment. However, when interest rates decline, caps restrict borrowers' access to lower market rates and incite refinancing (prepayment). The two variables LCCALL and PCCALL capture this option (and restrictive) effect by measuring the magnitude of interest rate change as a percentage of the respective cap limit. LCCALL measures the change in the ARM note rate since origination as a percentage of the lifetime cap, and PCCALL measures the potential note rate change since last adjustment (SPREAD) as a percentage of the period cap. Variable values less than one (100%) are out-of-the-money options, and variable values greater than one are in-the-money options. The greater the positive (negative) percentage change, the more valuable (less valuable) the caps to the ARM borrower and the lower (higher) the probability of default and prepayment.

The ARM borrower's age (ARMBAGE) and the ARM's current loan-to-value ratio (ARMLTV) do not measure unique contractual terms. They are included as simple tests, respectively, for the possibility that moving costs of ARM borrowers differ from the moving costs of FRM borrowers (a clientele effect) and the possibility that equity value with ARM financing fluctuates differently from equity value with FRM financing (not captured in SPREAD and EXPADJ). The ARMPTY is included as a measure of potential ARM payment shock.

Mortgage buydowns became a popular technique for lowering borrowers' initial payment burdens during the study period. Lengthy buydown periods are valuable (VALBDT) when the current market rate is higher than the buydown rate. This motivates the borrower to keep the mortgage outstanding and lowers the probability of default or prepayment.

The variables DEP, JINC, RENT, YRSCA, and YRSCJ are proxies for borrower moving costs. The number of dependents (DEP) reflects greater demands on household income and the likelihood of higher default probabilities. Income diversity is measured by a single/joint income dummy (JTINC) which models income stability and lower expected default rates for dual income borrowers. Recent renters (RENT) are presumed to be less adverse to returning to rental status and more likely to default. Households with greater tenure in their former dwellings (YRSCA) or original jobs (YRSCJ) prefer stability and are less likely to default. The impact of net worth (NWORTH) on default is indeterminate. Rising house prices serve as a reserve for delaying default (Vandell and Thibodeau 1985), but when house prices fall, rational borrowers simply use NWORTH to pay moving costs, increasing default.

## II. Data and Estimation Procedure

The data for this study come from the origination files of North American Mortgage Co. (NAMC), a private mortgage banking firm based in Houston, Texas. All of the loans are collateralized by Texas properties, most located in the Houston metropolitan area. In addition to volatile interest rates, this area experienced significant house price inflation prior to June 1983, followed by equally dramatic deflation (25% on average) from July 1983 until December 1985.

**Table II**

## Summary Statistics of Independent Variables

Entries are the maximum/minimum values and mean/standard deviation values for the modeled variables. Values are as of observation dates unless otherwise indicated. The data set consists of 879 observations: 411 ARM loans (178 defaults, 85 prepaids, and 148 currents) and 468 FRM loans (118 defaults, 197 prepaids, and 153 currents).

| Variable-Description | Maximum (Minimum) | Mean (Std. Deviation) | Unit of Measure |
|---|---|---|---|
| | **Property** | | |
| CLTV = ratio of amortized loan balance to house value adjusted for regional price changes | 181.0 (18.8) | 82.3 (23.5) | percentage of house value |
| | **Mortgage** | | |
| MAGE = mortgage age in months | 105.0 (3.0) | 32.6 (19.8) | months |
| SPREAD[a] = difference between the current market rate and current note rate as a percent of the current note rate | 104.3 (−3.4) | 9.3 (2.4) | percentage of current note rate |
| VALBDT = buydown term remaining in years if SPREAD is positive, zero otherwise | 4.6 (0.0) | 0.34 (.82) | years |
| | **Borrower** | | |
| BAGE = borrower's age in years at time of observation | 77.0 (21.4) | 37.9 (9.2) | years |
| CPTY = mortgage payment-to-income ratio including original taxes and insurance and adjusted for changes in the note rate and nominal changes in regional income at time of observation | 72.7 (0.4) | 20.0 (8.0) | percentage of current income |
| DEP = number of dependents at origination | 7.0 (0.0) | 1.5 (1.2) | number of dependents |
| JTINC = single or joint source of income at origination | 1.0 (0.0) | 0.49 (0.50) | single = 0, joint = 1 |
| NWORTH = net worth per dependent at origination in thousands | 12,505 (−183) | 165 (828) | thousand dollars |
| RENT = tenure status at origination | 1.0 (0.0) | 0.55 (0.50) | own = 0, rent = 1 |
| YRSCA = years at current address at origination | 44.0 (0.04) | 2.8 (4.1) | years |
| YRSCJ = years employed in same job at origination | 40.0 (0.0) | 4.8 (5.8) | years |
| YRSCW = years employed in same line of work at origination | 40.0 (0.0) | 7.7 (6.7) | years |
| | **Economic** | | |
| UNEM = regional unemployment rate | 10.3 (2.7) | 7.5 (1.6) | percent |

**Table II**—*Continued*

| Variable-Description | Maximum (Minimum) | Mean (Std. Deviation) | Unit of Measure |
|---|---|---|---|
| YLDCRV[a] = thirty-year treasury bond rate minus 1-year treasury bond rate | 2.7 (−0.2) | 1.8 (0.6) | difference in percentages |
| | ARM-specific (FRM values = 0)[b] | | |
| AFREQ = years between note rate-adjustment dates | 5.0 (1.0) | 3.0 (1.2) | years |
| ARMBAGE = BAGE times 0/1 ARM dummy | 69.0 (21.4) | 37.5 (9.2) | years |
| ARMLTV = CLTV times 0/1 ARM dummy | 181.0 (37.3) | 92.1 (18.9) | percentage of house value |
| ARMPTY = CPTY times 0/1 ARM dummy | 72.7 (0.4) | 21.1 (8.5) | percentage of current income |
| ARMYLDCRV = YLDCRV times 0/1 ARM dummy | 2.7 (−0.2) | 1.9 (0.6) | difference in percentages |
| EXPADJ[a] = expected adjustment: period cap or SPREAD, whichever is absolutely lower | 94.2 (−23.6) | 9.5 (19.0) | percentage of current note rate |
| LCAP[ac] = maximum lifetime rate change allowed as a percent of current note rate | 145.5 (21.4) | 63.7 (31.3) | percentage of current note rate |
| LCCALL[a] = difference between current note rate and original contract rate expressed as a percent of lifetime cap | 30.0 (−100.0) | −19.4 (21.8) | percentage of life cap |
| PCCALL[a] = difference between market rate and current note rate expressed as a percent of period cap | 426.5 (−387.5) | −8.47 (125.0) | percentage of period cap |

[a] The correlation matrix for the interest rate related variables is:

| | SPREAD | EXPADJ | LCAP | LCCALL | PCCALL |
|---|---|---|---|---|---|
| YLDCRV | −0.2145 | −0.0872 | 0.1497 | 0.2247 | −0.4285 |
| SPREAD | | 0.9379 | 0.7110 | −0.2258 | 0.6021 |
| EXPADJ | | | 0.8219 | −0.1333 | 0.3991 |
| LCAP | | | | 0.1018 | 0.2602 |
| LCCALL | | | | | −0.4748 |

[b] Statistics calculated from ARM-specific data only.

[c] Several lifetime caps were infinite. Best results were obtained by substituting 10 points for infinity.

The first NAMC ARM was originated in June 1980 while FRM originations occurred as early as 1962. Our observation period begins with the date of the first ARM default in June 1982 and concludes on December 31, 1985.[14] To form the data set, samples of 500 loans each were initially taken from each choice set

[14] Most of the ARMs in this sample were indexed to changes in the average offering rate of new FRMs as reported by the Federal Home Loan Bank Board.

(default, prepaid, and current).[15] After eliminating observations with missing values, the final choice-based sample-set contains 879 observations: 411 ARM loans (178 defaults, 85 prepaids, and 148 currents), and 468 FRM loans (118 defaults, 197 prepaids, and 153 currents). Summary statistics appear in Table II.

The estimation procedure is iterative maximum-likelihood, providing consistent estimates of asymptotic standard errors. Cosslett (1981) shows that the bias introduced by a choice-based sampling procedure—for the multinomial logit model with a complete set of alternative specific dummies (i.e., constant term in each equation)—is limited to the parameter estimates of the constant terms. An adjustment based on the ratio of sample choice (default, prepay, current) proportions to population choice proportions corrects the bias.[16]

## III. Results

The estimated utility weights appearing in Table III support the importance of equity over the ability-to-pay hypothesis of mortgage default. The traditional property and mortgage related variables are all statistically significant with the expected signs. The current payment-to-income ratio (CPTY) and unemployment (UNEM) variables are significant with "incorrect" signs in the default equation, and they are insignificant in the prepayment equation. Vandell and Thibodeau (1985) reported similar findings for payment-to-income ratios and suggested rigorous enforcement of underwriting standards may have accounted for these results. The positive sign of the current loan-to-value ratio (CLTV) in the default equation is, as expected, opposite its negative sign in the prepayment equation. This shows that borrowers are more likely to default than prepay if equity is negative or low, and they are more likely to prepay (presumably to "trade-up") if equity is positive and high. The seasoning terms (MAGE and MAGESQ) remain significant even after adjusting the CLTV for amortization.

Of particular interest in this study are the coefficients of the interactive terms. They indicate a unique ARM termination pattern in response to interest rate movements (movements that are both subsequent to origination and expected).

[15] The current loans could only be identified as current during the 18 months prior to December 1985. To extend the observation period for current loans back to June 1982, we subdivided the period from June 1982 to December 1985 into fourteen quarters. All 1,370 sampled loans, whether initially sampled as prepaid, defaulted, or current, were also classified as current in the quarters that preceded their termination date. Thirty loans were randomly selected from each quarter to compose a new sample of 420 current loans that spanned the full 42 months prior to December 1985.

[16] The adjustment necessary to correct for the intercept bias is:

$$\beta_{i0'} = \beta_{i0} - \ln(H_i/Q_i),$$

where

$i$ = default, prepay,
$\beta_{i0'}$ = true intercept for choice $i$,
$\beta_{i0}$ = estimated intercept for choice $i$,
$H_i$ = proportion of choice $i$ in sample ($H_d = 0.337$, $H_p = 0.321$), and
$Q_i$ = proportion of choice $i$ in population ($Q_d = 0.05$, $Q_p = 0.12$).

We know that FRMs terminate inversely to changes in interest rates because of the mortgage gains (losses) that accrue when market rates increase (decrease). But because ARMs generate smaller gains (losses) when interest rates increase (decrease), they are more likely (less likely) than FRMs to prepay. The ARM-specific EXPADJ variable confirms this behavior by offsetting the negative effect of the SPREAD variable on prepayment—its coefficient is twice that of SPREAD, and has the opposite sign. LCAP has a similar offsetting effect in the default equation.[17] With respect to expected interest rate changes, both FRMs and ARMs terminate in direct relation to YLDCURV, confirming the optimal prepayment strategy set forth by Chen and Ling (1989).[18] However, ARMs are less sensitive to expected rate changes as demonstrated by the negative sign of the interactive term ARMYLDCURV.

This basic termination response difference between ARMs and FRMs to interest rate changes can be minimized by low rate caps and less frequent rate adjustments. Period caps limit the magnitude of EXPADJ and, therefore, decrease (increase) the probability of ARM borrower prepayment when interest rates increase (decrease).[19] Likewise, lower life caps (LCAP) and longer adjustment periods (AFREQ) decrease the likelihood of default. The hypothesized secondary effect of lifetime caps and period caps is also confirmed. The negative sign of LCCALL offsets the positive effect of lifetime caps (LCAP) in the default equation, and PCCALL offsets the positive effect of EXPADJ in the prepayment equation. Hence caps do create a valuable "call" effect on below-market financing as mortgage rates increase beyond the cap limit. Likewise, when rates fall substantially borrowers terminate more quickly to avoid the cap restrictions.

While previous studies find borrower characteristics important in explaining mortgage default, there is no consistency in the set of variables proving statistically significant. Our results indicate four characteristics are statistically valid motivations for mortgage termination: previous renters and older borrowers are more likely to default, suggesting they have lower default costs;[20] borrowers with a long history of employment in their current line of work are less likely to default; and net worth is positively correlated to default, implying its use as a source for paying moving costs rather than as a reserve for deferring default.

Net worth is the only borrower characteristic we find significant in explaining prepayment; otherwise the property (equity) and mortgage characteristics are dominant. These results suggest that refinancing considerations, in which moving

[17] Regression runs with LCAP omitted also resulted in a significantly positive EXPADJ for the default equation. As seen in Table II, LCAP and EXPADJ are 0.822 correlated.

[18] Borrowers delay prepayment when interest rates are expected to fall, waiting for an even better (lower) rate later. They accelerate prepayment when rates are expected to rise, avoiding an even worse (higher) rate later.

[19] A separate regression was run with an interactive SPREAD term substituted for EXPADJ. The results were robust, but the equation with EXPADJ had a higher level of statistical significance. We read this to indicate that borrowers do consider the adjustment limits imposed by period caps (used to specify EXPADJ) when making their termination decisions.

[20] Webb (1982) notes that borrowers under the age of 44 have the highest income growth rates and the lowest levels of variability. Staff members of North American Mortgage Co. note older borrowers seem less concerned about future credit ratings, because revolving credit lines are established.

**Table III**

## Multinomial Logit Regression Results

These multinomial logit regression coefficients represent indirect utility weights of each influencing variable on the calculation of the probabilities of default and prepayment. The goodness of fit chi-squared statistic is 484.63 with 48 degrees of freedom and 879 observations. 2 log-likelihood = 1468.55.

| Variable-Description | Default | Prepay |
|---|---|---|
| Property | | |
| Constant | −9.856****[a] | −0.509[a] |
| | (−6.74) | (−1.11) |
| CLTV = ratio of amortized loan balance to house value | 0.036*** | −0.032*** |
| adjusted for regional price changes | (3.83) | (−3.92) |
| Mortgage | | |
| MAGE = mortgage age in months | 0.123*** | 0.070*** |
| | (5.55) | (3.79) |
| MAGESQ = mortgage age squared | −0.00098*** | −0.000697*** |
| | (−4.04) | (−3.65) |
| SPREAD[a] = difference between the current market rate and | −0.022*** | −0.029*** |
| current note rate as a percentage of the current note rate | (−2.75) | (−4.27) |
| VALBDT = buydown term remaining in years if SPREAD is | −0.106 | −0.504** |
| positive, zero otherwise | (−0.60) | (−2.10) |
| Borrower | | |
| BAGE = borrower's age in years at time of observation | 0.086*** | −0.023 |
| | (4.60) | (−1.25) |
| CPTY = mortgage payment-to-income ratio including | −0.040* | −0.004 |
| original taxes and insurance and adjusted for changes in | (1.61) | (−0.18) |
| the note rate and nominal changes in regional income at | | |
| time of observation | | |
| DEP = number of dependents at origination | 0.081 | −0.040 |
| | (0.91) | (−0.47) |
| JTINC = single or joint source of income at origination | −0.208 | 0.099 |
| | (−1.00) | (0.50) |
| NWORTH = net worth per dependent at origination in | 0.000313** | 0.000305** |
| thousands | (1.77) | (1.75) |
| RENT = tenure status at origination | 0.649*** | −0.111 |
| | (2.67) | (−0.50) |
| YRSCA = years at current address at origination | −0.009 | 0.003 |
| | (−0.29) | (0.13) |
| YRSCJ = years employed in same job at origination | −0.023 | 0.018 |
| | (−0.91) | (0.80) |
| YRSCW = years employed in same line of work at | −0.078*** | −0.002 |
| origination | (−3.53) | (−0.07) |
| Economic | | |
| UNEM = regional unemployment rate | −0.262*** | −0.057 |
| | (−3.72) | (−0.92) |
| YLDCRV = thirty-year treasury bond rate minus 1-year | 1.05*** | 1.01*** |
| treasury bond rate | (3.43) | (3.88) |
| ARM = specific (FRM values = 0) | | |
| AFREQ = years between note-rate-adjustment dates | −0.285** | 0.016 |
| | (−1.99) | (0.09) |
| ARMBAGE = BAGE times 0/1 ARM dummy | −0.009 | −0.010 |
| | (−0.57) | (−0.59) |

**Table III**—*Continued*

| Variable-Description | Default | Prepay |
|---|---|---|
| ARMLTV = CLTV times 0/1 ARM dummy | 0.008 | −0.002* |
| | (0.70) | (−1.45) |
| ARMPTY = CPTY times 0/1 ARM dummy | 0.003 | 0.041* |
| | (0.10) | (1.58) |
| ARMYLDCRV = YLDCRV times 0/1 ARM dummy | −0.703** | −0.477 |
| | (−1.79) | (−1.22) |
| EXPADJ = expected adjustment: period cap or SPREAD, | 0.006 | 0.066*** |
| whichever is absolutely lower | (0.38) | (3.54) |
| LCAP = maximum lifetime rate change allowed as a | 0.026*** | −0.008 |
| percentage of current note rate | (2.65) | (−0.69) |
| LCCALL = difference between current note rate and original | −0.017** | −0.002 |
| contract rate expressed as a percentage of lifetime cap | (−2.01) | (−0.69) |
| PCCALL = difference between market rate and current note | −0.041 | −0.003** |
| rate expressed as a percentage of period cap | (−0.23) | (−1.67) |

[a] Unadjusted intercepts are −7.852 and 1.196, respectively.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

costs are irrelevant, weigh heavily relative to moving considerations in the prepayment decisions of borrowers. Also, both FRM and ARM borrowers delay prepayment if the remaining buydown period is valuable (VALBDT).

The interaction terms of ARM with BAGE, CLTV, and CPTY are all insignificant in the default equation. We conclude, therefore, that differences between FRM and ARM default experience result only from the contractual provisions of ARMs (i.e. period caps, life caps, and adjustment frequencies) and not from borrower clientele effects. However, the modest level of significance in the prepayment results suggests ARM borrowers may be more sensitive to equity and payment levels when making prepayment decisions.

## V. Simulation Results

In an effort to better assess the difference between ARM and FRM termination behavior, we simulate the estimated equation at the mean sample values. The results appear in Table IV. The first row indicates the termination probabilities of an "average" ARM and FRM (i.e. mortgages with variable values equal to the means of the sample). In the rows below these termination probabilities are their incremental changes for a given unit change in variable values. For example, the default probabilities of our "average" ARM and FRM are 17.1 and 9.3%, respectively.[21] If the current loan-to-value ratio (CLTV) were to increase by 1%, then

[21] Recall the sample is choice-based to include large proportions of defaulted and prepaid loans. Therefore, these "average" probabilities may appear abnormally high when compared with termination probabilities in the total population.

## Table IV
## Simulated Incremental Changes in Termination Probabilities per Unit Change in Independent Variables

Incremental probabilities are the changes in probabilities associated with one unit changes in the corresponding independent variables. They are computed as the first partial derivatives of the cumulative logistic distribution with respect to each variable and are then evaluated at the mean values of all variables. For example, the marginal default probabilities are calculated as:

$$\frac{\partial P_d}{\partial Z_i} = \frac{(\beta_{di} e^{Z\beta_d})(1 + e^{Z\beta_d} + e^{Z\beta_p}) + (e^{Z\beta_d})(\beta_{di} e^{Z\beta_d} + \beta_{pi} e^{Z\beta_p})}{(1 + e^{Z\beta_d} + e^{Z\beta_p})^2},$$

where $P_d$ = probability of a household choosing to default (see equation (1)), $Z$ = vector of independent variables. Here we use sample mean values, $Z_i$ = value of variable $i$ (sample means used here), $\beta_d$ = vector of coefficients for default equation, $\beta_{di}$ = coefficient on variable $i$ in default equation, $\beta_p$ = vector of coefficients for prepayment equation, and $\beta_{pi}$ = coefficient on variable $i$ in prepayment equation.

| Variable-Description | Variable Mean | Incremental ARM Probabilities | | Incremental FRM Probabilities | |
|---|---|---|---|---|---|
| | | Default | Prepay | Default | Prepay |
| Total Termination Probabilities at Mean Variable Values | | 17.3 | 10.6 | 9.3 | 15.9 |
| Property | | | | | |
| CLTV = ratio of amortized loan balance to house value adjusted for regional price changes | 87.3 | 0.66 | −0.34 | 0.32 | −0.60 |
| Mortgage | | | | | |
| MAGE = mortgage age in months | 32.6 | 0.49 | 1.19 | 1.35 | 1.67 |
| MAGESQ = mortgage age squared | 1062.76 | −0.02 | −0.01 | −0.01 | −0.02 |
| SPREAD = difference between the current market rate and current note rate as a percent of the current note rate | 9.3 | −0.49 | −0.43 | −0.27 | −0.64 |
| VALBDT = buydown term remaining in years if SPREAD is positive, zero otherwise | 0.34 | −3.04 | −6.85 | −1.82 | −10.59 |

**Table IV**—*Continued*

| Variable-Description | Variable Mean | Incremental ARM Probabilities: Default | Incremental ARM Probabilities: Prepay | Incremental FRM Probabilities: Default | Incremental FRM Probabilities: Prepay |
|---|---|---|---|---|---|
| **Borrower** | | | | | |
| BAGE = borrower's age in years at time of observation | 37.9 | 1.67 | −0.11 | 0.84 | −0.32 |
| CPTY = mortgage payment-to-income ratio including original taxes and insurance, and adjusted for changes in the note rate and nominal changes in regional income at time of observation | 20 | −0.81 | −0.14 | −0.41 | −0.15 |
| DEP = number of dependents at origination | 1.5 | 1.54 | −0.35 | 0.76 | −0.68 |
| JTINC = single or joint source of income at origination | 0.49 | −3.97 | 0.85 | −1.96 | 1.67 |
| NWORTH = net worth per dependent at origination in thousands | 165 | 0.007 | 0.005 | 0.004 | 0.007 |
| RENT = tenure status at origination | 0.55 | 12.75 | −0.04 | 6.40 | −1.13 |
| YRSCA = years at current address at origination | 2.8 | −0.17 | 0.02 | −0.09 | 0.05 |
| YRSCJ = years employed in same job at origination | 4.8 | −0.43 | 0.19 | −0.21 | 0.33 |
| YRSCW = years employed in same line of work at origination | 7.7 | −1.56 | −0.20 | −0.79 | −0.18 |
| **Economic** | | | | | |
| UNEM = regional unemployment rate | 7.5 | −5.34 | −1.32 | −2.73 | −1.65 |
| YLDCRV = thirty-year treasury bond rate minus one-year treasury bond rate | 1.8 | 22.83 | 15.56 | 12.11 | 22.73 |
| **ARM = specific (FRM values = 0)** | | | | | |
| AFREQ = years between note rate-adjustment dates | 3 | −5.66 | −0.41 | 0 | 0 |
| ARMBAGE = BAGE times 0/1 ARM dummy | 37.9 | −0.20 | −0.15 | 0 | 0 |
| ARMLTV = CLTV times 0/1 ARM dummy | 82.3 | 0.16 | −0.01 | 0 | 0 |
| ARMPTY = CPTY times 0/1 ARM dummy | 20 | 0.14 | 0.55 | 0 | 0 |
| ARMYLDCRV = YLDCRV times 0/1 ARM dummy | 1.8 | −14.92 | −7.80 | 0 | 0 |
| EXPADJ = expected adjustment: period cap or SPREAD, whichever is absolutely lower | 9.5 | 0.24 | 0.88 | 0 | 0 |
| LCAP = maximum lifetime rate change allowed as a percent of current note rate | 63.7 | 0.50 | −0.05 | 0 | 0 |
| LCCALL = difference between current note rate and original contract rate expressed as a percent of lifetime cap | −19.4 | −0.34 | −0.06 | 0 | 0 |
| PCCALL = difference between market rate and current note rate expressed as a percent of period cap | −8.5 | −0.82 | −0.13 | 0 | 0 |

the ARM's default probability would increase by 0.66% and the FRM's probability would increase by 0.32%.

From these mean-based simulations, we make the following observations. The ARM's default probability is both greater than the FRM probability and more sensitive to variable changes. The opposite is true for prepayment. A complete interpretation of these results requires consideration of the simultaneous effect of the interactive terms. For example, a 1% expected increase in long-term interest rates over short-term interest rates (YLDCRV) suggests the ARM default probability would increase by 22.8% and the FRM default probability would increase by only 12.1%. However, combining this result with the negative interactive term effect of ARMYLDCRV (−14.9%) gives a net default probability change for the ARM of only 7.9%. In a similar fashion, SPREAD should be netted against EXPADJ, BAGE against ARMBAGE, CLTV against ARMLTV, and CPTY against ARMPTY.

## VI. Conclusions

This study focuses on the household-specific choice of ARM termination vis-à-vis FRM termination during periods of volatile interest rates and volatile house-price changes. The results support the option-based notions that current equity net of moving costs dominates in the case of the default decision and that mortgage and property (equity) variables dominate in the case of prepayment.

The expectation of lenders and insurers that ARMs have greater default risk than FRMs appears justified. In contrast, ARMs appear to have lower prepayment probabilities. The degree of ARM termination risk is directly related to the size of the rate caps (both periodic and lifetime) and the length of the adjustment period. Caps also create a secondary effect when interest rates move substantially. Low caps become valuable call options on below-market financing (delaying termination) when rates rise substantially above the cap limit, but they restrict borrowers' access to cheaper financing (increasing termination) when rates fall substantially below the cap limit.

### REFERENCES

Campbell, T. S. and J. K. Dietrich, 1983, The determinants of default on insured conventional residential mortgage loans, *Journal of Finance* 38, 1569–1581.

Chen, A. H. and D. C. Ling, 1989, Optimal mortgage refinancing with stochastic interest rates, *Journal of the American Real Estate and Urban Economics Association* 17, 278–299.

Cosslett, S. R., 1981, Efficient estimation of discrete choice models, in C. F. Manski and D. McFadden, eds.: *Structural Analysis of Discrete Data with Economic Applications* (MIT Press, Cambridge), p. 84.

Cunningham, D. F. and P. H. Hendershott, 1984, Pricing FHA mortgage default insurance, *Housing Finance Review* 3, 373–392.

Epperson, J. F., J. B. Kau, D. C. Keenan, and W. J. Muller, 1985, Pricing default risk in mortgages, *Journal of the American Real Estate and Urban Economics Association* 13, 261–272.

Field, A. and H. Cassidy, 1977, Simulation analysis of alternative mortgage instruments, *Journal of the American Real Estate and Urban Economics Association* 5, 411–433.

Foster, C. and R. Van Order, 1984, An option-based model of mortgage default, *Housing Finance Review* 3, 351–372.

———, 1985, FHA terminations: A prelude to rational mortgage pricing, *Journal of the American Real Estate and Urban Economics Association* 13, 273–291.

Gau, G. W., 1978, A taxonomic model for the risk-rating of residential mortgages, *Journal of Business* 51, 687–706.

Green, J. and J. Shoven, 1986, The effects of interest rates on mortgage prepayments, *Journal of Money, Credit and Banking* 18, 41–59.

Jackson, J. R. and D. L. Kaserman, 1980, Default risk on home mortgage loans: A test of competing hypotheses, *The Journal of Risk and Insurance* 47, 678–690.

Lea, M. J. and P. M. Zorn, 1986, Adjustable rate mortgages, fluctuations in the economic environment and lender portfolio change, *Journal of American Real Estate and Urban Economics Association* 14, 432–447.

Madalla, G. S., 1983, *Limited-Dependent and Qualitative Variables in Econometrics* (Cambridge University Press, New York).

Peters, H. F., S. M. Pinkus, and D. J. Askin, 1984, Figuring the odds: A model of prepayments, *Secondary Mortgage Markets* 1, 18–23.

Sa-Aadu, J., 1988, Legal restrictions, credit allocation and default risk under fixed and adjustable rate mortgages, *Housing Finance Review* 7, 225–247.

Swan, Craig, 1982, Pricing private mortgage insurance, *Journal of American Real Estate and Urban Economics Association* 10, 276–296.

Vandell, K. D., 1978, Default risk under alternative mortgage instruments, *Journal of Finance* 33, 1279–1296.

Vandell, K. and T. Thibodeau, 1985, Estimation of mortgage defaults using disaggregate loan history data, *Journal of the American Real Estate and Urban Economics Association* 13, 292–316.

Von Furstenberg, G. M., 1969, The default risk on FHA-insured home mortgages, *Journal of Finance* 24, 459–477.

Webb, B., 1982, Borrower risk under alternative mortgage instruments, *Journal of Finance* 37, 169–183.