The Default Risk of Adjustable Rate Mortgages: A Preliminary Assessment of the Empirical Evidence

Peter M. Zorn, Cornell University[1]

ABSTRACT

This paper provides a preliminary assessment of the default risk of adjustable rate mortgages (ARMs) by using a subset of existing empirical studies as the basis for a series of simple simulations. The results of these simulations are not entirely consistent, however they do suggest that: (1) the default risk of ARMs is likely to be only slightly higher than that of fixed rate mortgages, (2) ARMs with 3 year adjustment terms will have slightly lower default rates than ones with 1 year adjustment terms, and (3) interest rate caps have no significant impact on default risk. The analysis also demonstrates the crucial role of mortgage prepayment in determining default risk.

I. INTRODUCTION

Since their widespread introduction in 1983, adjustable rate mortgages (ARMs) have become a fixture in the market. One obvious characteristic of ARMs is that they shift some of the interest rate risk from lenders to borrowers. Less clear, however, is ARMs implication for default risk. Of particular concern is the possibility that default rates of ARMs will be significantly higher than those of fixed rate mortgages (FRMs). The purpose of this paper is to explore the empirical evidence on the relative default risk of ARMs.

Empirical research on the determinants of mortgage default is voluminous. Recent studies include Campbell and Dietrich (1983), Foster and Van Order (1984), Jackson and Kaserman (1980), Lea and Zorn (1986), Manchester (1985), Peters et al. (1984b), Vandell (1978), Vandell and Thibodeau (1985), Webb (1982), and Zorn and Lea (1989). Unfortunately empirical studies such as these do not by themselves provide a clear measure of default risk. This assessment requires determining the probability that borrowers will default over the term of their mortgage, which depends on future values of the determinants of default. Because the determinants of default are treated as exogenous, empirical studies provide no method for directly predicting default in the future.

Researchers interested in assessing default risk have, consequently, been forced to consider alternative approaches. Most popular among the choices have been options pricing models, which characterize the time path of the determinants of default ("state" variables) using either theoretically motivated stochastic differential equations, or empirically derived interactions between the state variables.[2]

However both of these approaches face pragmatic problems since their computational difficulties increase dramatically with the number of state variables. This means in practice that the behavioral models underlying these analyses are quite simple, far more so than in the empirical works cited above. In an effort to more fully exploit the comparative richness of the existing empirical models of default, an alternative to the sophisticated options pricing models is pursued in this paper. In particular, the computational difficulties of these approaches are significantly reduced by considering only a small subset of possible time paths of the state variables.

The motivation for this exercise is twofold. First, to determine the extent to which the existing empirical models agree on their implications for default risk, and second, to provide a preliminary assessment of the relative default risk of ARMs.[3] The analysis consists of two sets of simulations conducted on a subset of the empirical models cited above. The first set of simulations attempts to assess the marginal impact of changes in the determinants of the relative default risk of ARMs by comparing the relative default rates of various ARMs (across different empirical models) for two basic states of the world. The second set of simulations attempts a limited assessment of simultaneous impacts by simulating ARM default rates over the historical period of 1970 through 1984.

While this approach is less rigorous than the standard options pricing models, it does allow for a useful preliminary assessment of the existing empirical evidence on default risk. It is interesting, then, that the analysis shows a general lack of consistency across the empirical studies. However the results do suggest that the default risk of ARMs will be slightly higher than that for FRMs, that ARMs with 3 year adjustment terms will have slightly lower default rates than those with 1 year adjustment terms, and that interest rate caps have no significant impact on default risk.

[1]Assoc. Professor, Consumer Economics & Housing

[2]Hendershott and Van Order (1987) and Boyle (1977) provide a general discussion of the techniques associated with options pricing models.

[3]Vandell (1985) has undertaken a similar study, however his technique and emphasis differs from that of this paper.

II. DISCUSSION OF THE ISSUES

As argued above, empirical studies on their own are not sufficient to assess default risk. This point can be most easily demonstrated by considering the mathematical expression for the probability that a mortgage will default over its lifetime, illustrated here for an ARM.

$$(1) \quad P(\text{ARM defaults}) = 1 - \prod_{t=1}^{T} [1 - P(\text{ARM exists in } t) \cdot P(\text{ARM defaults in } t;\ \text{exists})]$$

where

$$P(\text{ARM exists in } t) = \prod_{i=1}^{t-1} [1 - P(\text{ARM defaults in } i;\ \text{exists}) - P(\text{ARM prepays in } i;\ \text{exists})]$$

Equation (1) highlights the necessity of modeling the determinants of default over time, a factor not typically incorporated into empirical research. It also highlights the crucial role of mortgage prepayment in a proper assessment of default risk.[4]

To assess the default risk of ARMs, three empirical studies of default are used as the basis for two simple sets of simulations. Using the parameter estimates of each study, the probability that borrowers default over the term of their mortgage is separately simulated for FRMs and ARMs. For each set of these simulations, the probabilities of default are combined into default ratios to give the probability of default with an ARM relative to that with an FRM.

$$(2) \quad \text{Default Ratio} = \frac{P(\text{ARM defaults})}{P(\text{FRM defaults})}$$

Relative rather than absolute default risk is considered for two reasons. First, it is argued that FRMs provide an appropriate standard from which to address the default risk of ARMs. Second, the empirical studies of default underlying these simulations rely on different independent variables. For this reason it is often difficult to insure that the absolute level of default is comparable across studies. Expressing default risk in relative terms greatly reduces the magnitude of this problem.

A. Default Studies

Three of the existing empirical studies are used as a basis for the simulations in this paper -- Campbell and Dietrich (1983), Vandell (1978), and Zorn and Lea (1989).[5] Consistent with other studies, they presume that mortgage default is motivated by either: (1) ability-to-pay, which argues that defaults occur when borrowers have difficulties in meeting their required mortgage payments, or (2) equity, which argues that borrowers default when the market value of their mortgage (the present value of their future expected mortgage payments) is greater than the market value of their property.

Interested readers are directed to the studies for further details of their estimation. However, it is worth noting that these studies are all estimated on data of a single instrument type (FRM or ARM), which may limit their ability to accurately predict defaults with alternative instruments.[6]

B. Prepayment Studies

One of the few studies to empirically estimate the probability of mortgage prepayment is that of Foster and Van Order (1985).[7] Utilizing FRM data, it develops and estimates a simple model based on financial motivations, arguing that prepayment decreases as the market value of a mortgage declines relative to its par value. However mobility considerations are likely to be another important determinant of mortgage prepayment, particularly with the enforcement of "due-on-sale" clauses on conventional mortgages.

An alternative measure of the probability of mortgage prepayment is provided in Campbell et al. (1981). This paper utilizes FHA experience to provide average prepayment rates for each year in the term of a mortgage. These averages cannot account for the effect of fluctuations in economic variables on borrowers' financial incentives to prepay, however they may adequately capture variations in prepayment due to the average borrower's mobility decisions. As such, these average prepayment rates offer an interesting alternative to the estimates provided by Foster and Van Order. Consequently, both sets of prepayment estimates are used in the simulations that follow, although space limitations allow only the results based on the Foster and Van Order model to be presented.

III. SIMULATIONS

Two sets of simulations are conducted in this study. The emphasis of the first set of

---

[4]This point was previously made by Vandell (1978). Note, however, that he incorrectly computes the probability that a mortgage will exist in any time period.

[5]The other existing empirical studies are not included in this analysis because they are either difficult to simulate or otherwise inappropriate.

[6]This point is discussed in Vandell (1978).

[7]Other studies of mortgage prepayment include Meador (1983), Peters et al. (1984a), and Waldman et al. (1985). Foster and Van Order (1985) is the most rigorous of these studies.

simulations is on assessing the marginal impact of anticipated and unanticipated changes in determinants of the relative default risk of ARMs. The second set of simulations broadens the focus to address simultaneous impacts. Using the economic history of the years 1970 through 1984, it attempts to determine how default rates vary in at least one realistic state of the world. The results of the simulations are provided in the form of the default ratios specified in equation (2). The probabilities necessary for determining these ratios are derived as in equation (1).

A. Assessing Marginal Impacts

This first set of simulations estimates probabilities of default by simulating borrowers' decisions over the term of their mortgages. Each simulation considers a marginal variation from the base case, which was designed so that the probability of default for the FRM and ARMs is identical (the default ratio equals one). Because this is an assessment of marginal impacts (i.e. all other variables are held constant), differences in the default probabilities of the mortgage instruments can only occur with a divergence in their contract rates. For this reason the concentration is on assessing the impact of factors that affect the contract rates of ARMs relative to those of an FRM. These include: (1) the length of the adjustment term, (2) contract rate caps, (3) initial contract rate discounts (teasers), and (4) anticipated and unanticipated changes in interest rates over time.

Four ARM instruments are considered to account for the first two factors: (1) an ARM with a one year adjustment term and no caps (ARM1), (2) an ARM with a one year adjustment term, a 200 basis point time-of-adjustment cap, and a 500 basis point life-of-loan cap (ARM1CAP), (3) an ARM with a three year adjustment term and no caps (ARM3), and (4) an ARM with a three year adjustment term, a 200 basis point time-of-adjustment cap, and 500 basis point life-of-loan cap (ARM3CAP).[8]

The contract rate for each mortgage is set so that, at the time of origination, the present value of expected future mortgage payments equals the amount of the loan. At the time of adjustment, the contract rate for ARMs can vary depending on the value of the market contract rate and the constraints imposed by any rate caps. The market contract rate for ARMs is the sum of an index, plus a margin that remains constant over time. The margin is composed of two components, a portion that is common across all mortgages (including the FRM), and a portion that differs for each ARM. The variable portion accounts for the unique characteristics across ARMs, such as initial discounts and rate caps, and adjusts to equate the present value of expected mortgage payments to the amount of the loan (at the time of origination).[9]

The contract rate for the FRM is computed by adding the common margin to the expected future value of the index in each period over the term of the mortgage, and deriving a constant interest rate that provides an equivalent yield over the same period. The starting values for each simulation, as well as the implied margins for the ARMs, are given in the Appendix. In addition it is assumed that borrowers make a downpayment of 20%, the mortgage term is 25 years, household income is $25,000, and the house price is $75,000.

In the first simulation all four ARMs are offered with an initial discount (teaser) of 300 basis points. Simulations 2 through 5 address the issue of changes in the index over time. To simplify the simulations the index is constrained to change either continuously (in simulations 2 and 3) or with a single discrete shock (in simulations 4 and 5). In simulations 2 and 4 the market is assumed to have perfect foresight, perfectly predicting the future increase in interest rates. In simulations 3 and 5 the increase in rates is unanticipated. Further, in simulation 3 expectations are assumed to never adjust to the 10% yearly increase in the index rate.

The results of these simulations are presented in Table I. **A priori** it is expected that default ratios will be less than one for simulations 1, 2, and 4, simulations in which there is an anticipated increase in the contract rates of ARMs. Under this circumstance ARMs begin at lower contract rates than the FRM, reducing early probabilities of default. Higher contract rates occur in the future, but their effect is discounted by the probability of mortgage termination in previous periods. For the opposite reason it is expected that default ratios will be greater than one for simulations 3 and 5, where there is an unanticipated increase in the contract rates of ARMs. Expectations in this regard are generally met, with one exception. In particular, the default ratios from simulation 5 are generally less than one.

The impact of changes in the characteristics of the ARMs is harder to predict a **priori**. However the simulation results suggest that this impact is small -- caps and the length of the term of adjustment generally have little impact on default risk. Nonetheless there is some indication that the default risk of ARMs with 3

[8]100 basis points equal 1 percent.

[9]To avoid the simultaneity problem inherent in computing the margins, the contract rates, and the market value of the mortgages, it is assumed that: (1) prepayment probabilities are the average FHA rate of prepayment, and (2) the probability of future default is zero. These assumptions are justified primarily on the grounds of expediency.

Table I. Results From Simulations Assessing Marginal Impacts: Prepayment Rates Based on Foster-Van Order Model

Simulation	Empirical Study	Default Ratios			
		ARM1	ARM1CAP	ARM3	ARM3CAP
#1	Campbell-Dietrich	0.9418	0.9304	0.8818	0.9043
	Vandell	0.9197	0.9021	0.8248	0.8314
	Zorn-Lea	0.9591	0.9522	0.9238	0.9315
#2	Campbell-Dietrich	0.9627	1.0138	0.9596	1.0149
	Vandell	0.8024	0.8565	0.8068	0.8652
	Zorn-Lea	0.9338	0.9417	0.9373	0.9478
#3	Campbell-Dietrich	0.9663	0.9633	0.9554	0.9535
	Vandell	1.1374	1.1243	1.0808	1.0728
	Zorn-Lea	1.0687	1.0625	1.0544	1.0497
#4	Campbell-Dietrich	0.9102	0.9103	0.9020	0.9253
	Vandell	0.8777	0.8751	0.8777	0.8925
	Zorn-Lea	0.9470	0.9480	0.9470	0.9584
#5	Campbell-Dietrich	0.8642	0.8682	0.8642	0.8730
	Vandell	1.0104	1.0065	1.0104	0.9967
	Zorn-Lea	0.9514	0.9589	0.9514	0.9614

year terms of adjustment is less than that for ARMs with 1 year terms.

There also appears to be little consistency regarding estimates of default risk across empirical studies. While the studies generally agree as to whether the default risk for ARMs is more or less than that for the FRM, the value of the default ratio often varies considerably across studies in a given simulation. Finally, despite rather large changes in interest rates, the probability of default with ARMs is generally within 10% of that of the FRM (the default ratio is between 0.90 and 1.10).[10]

B. An Historical Assessment

In this set of simulations, 15 years of historical data are used to estimate probabilities of default. The previous simulations are useful in isolating the effects of independent changes in the economy, however fluctuations in the actual economic environment occur simultaneously, and often unpredictably. Simulations based on past economic conditions offer an indication of the relative default risk of ARMs in at least one real state of the world.

To capture the impact of varying economic conditions over the 15 years of 1970 through 1984, default ratios are derived for loans originating in three time periods -- 1970, 1975, and 1980. Because the last year of the data is 1984, these default ratios are based on the probabilities that borrowers default in any year from the time of origination through 1984.

The overall approach of these simulations is similar to that of the previous set, with the exception that the values of the economic variables are determined from the historical record. Household income, house price, and the unemployment rate are assumed to be equal to the yearly median income, median sale price of existing single family dwellings, and national unemployment rate, respectively.

For each year, estimates of yearly market interest rates for the next 30 years are computed by a program developed at the Federal Home Loan Mortgage Corporation. The estimated yearly interest rates are used to compute the indices determining the contract rates of the

[10] In addition, there are large differences between the default ratios provided in Table 2 and those obtained using the prepayment rates of Campbell et al. This emphasizes the critical role of prepayment in assessing default risk.

Table II. Results From Historical Simulations: Prepayment Rates Based on Foster-Van Order Model

	Year of Origination/	Empirical Study	Default Ratios			
			ARM1	ARM1CAP	ARM3	ARM3CAP
WITHOUT TEASER	1970	Campbell-Dietrich	1.2037	1.2240	1.1678	1.1717
		Vandell	1.0927	1.2139	1.2372	1.2782
		Zorn-Lea	1.2087	1.2129	1.1375	1.1451
	1975	Campbell-Dietrich	1.0579	1.0704	1.0581	1.0516
		Vandell	1.2821	1.3055	1.3314	1.2591
		Zorn-Lea	0.9956	1.0146	0.9973	1.0091
	1980	Campbell-Dietrich	1.0751	1.1830	0.9681	1.0018
		Vandell	1.1041	1.2878	0.9590	1.0189
		Zorn-Lea	1.0645	1.0962	1.0108	1.0143
WITH TEASER	1970	Campbell-Dietrich	1.1854	1.2064	1.1963	1.2161
		Vandell	1.0518	1.1436	1.1810	1.2825
		Zorn-Lea	1.2042	1.2184	1.2038	1.2202
	1975	Campbell-Dietrich	1.0372	1.0510	1.0394	1.0338
		Vandell	1.2447	1.2716	1.2442	1.1135
		Zorn-Lea	0.9912	1.0104	1.0158	1.0505
	1980	Campbell-Dietrich	1.0597	1.0520	0.8774	0.9395
		Vandell	1.0829	1.0916	0.8364	0.9393
		Zorn-Lea	1.0574	1.0204	0.9793	1.0038

loans, as well as the market value of the mortgages. The contract rate for the FRM is assumed to be set at 200 basis points above the interest rate on 10-year government bonds. Market contract rates for the one and three year ARMs are based on the one and three year government bond rates, respectively.

The margins for ARMs without an initial discount are set as follows: 200 basis points for ARM1, 250 basis points for ARM1CAP, 225 basis points for ARM3, and 275 basis points for ARM3CAP.[11] The margins for ARMs with an initial 300 basis point teaser are set as follows: 225 basis points for ARM1, 275 basis points for ARM1CAP, 275 basis points for ARM3, and 350 basis points for ARM3CAP.[12]

The results of these simulations are presented in Table II. These results suggest that ARMs have greater default risk than FRMs -- the default ratios are generally greater than one. Note however that the difference in default risk is typically not large, with the default risk of ARMs generally within 10% of that of the FRM. Consistent with this finding, ARMs with 3 year adjustment terms generally have lower default risk than ARMs with 1 year adjustment terms.

[11]The value of these margins is consistent with recent market experience as found in periodic surveys by the Federal Home Loan Mortgage Corporation.

[12]The premium for the initial discount is based on the margins derived from the first set of simulations assessing marginal impacts (see Table I).

This is particularly true with loans originated in 1980, when the yield curve was downward sloping.[13]

Despite the wide fluctuations in interest rates during this period, there is typically little consistent difference between the default risk of capped and uncapped ARMs. The exception to this is with loans originated in 1980. Because there was a large decrease in interest rates early in the life of these mortgages, capped ARMs are found to have a greater default risk than uncapped ARMs.[14]

Although there is a general lack of consensus across these empirical studies, there is a basic consistency between the default ratios based on Campbell and Dietrich and Zorn and Lea. It is also interesting to note that, although default ratios based on Vandell are often at variance with the other studies, they are relatively robust with respect to changes in prepayment rates and the introduction of teasers.[15]

IV. CONCLUSIONS

The lack of consistency in predictions of default risk across empirical studies, combined with the important but empirically unexplored role of prepayment in determining default risk, makes drawing conclusions from these simulations somewhat risky. Nonetheless, the analyses do offer the opportunity to draw several tentative conclusions.

In particular, general implications can be drawn from the relatively consistent findings of simulations based on the work of Campbell and Dietrich and Zorn and Lea. First, if the 15 year historical record is any indication, default risk with ARMs will typically be higher than that with FRMs. However the difference in risk will be rather small -- in the range of 10%. Given the generally low rates of default with FRMs, and the unusually large fluctuations in interest rates since 1970, the slightly higher predicted default risk for ARMs may not be cause for concern.

Consistent with the above findings, the simulation results imply that ARMs with 3 year terms of adjustment will generally have slightly lower default risk than those with 1 year terms. Surprisingly, it is also found that interest rate caps (at least 200 basis point time-of-adjustment and 500 basis point life-of-loan caps) offer little significant reduction in default risk. In fact, in the historical simulation caps increased the risk of default for ARMs originated in 1980. This suggests that the emphasis on interest rate caps for ARMs may be misplaced.

Finally, this analysis offers two suggestions for improving future empirical research on default. Foremost in importance is the necessity of incorporating the prepayment decision into studies of mortgage default. Before an accurate measure of default risk can be obtained, empirical studies must simultaneously estimate the determinants of prepayment and default.

In addition, the simulations demonstrate an unfortunate lack of consensus among empirical studies of default. Given the relative consistency in the models underlying these studies, this lack of consensus is cause for concern. Variations in data offer one possible explanation for these differences. Improvements in data are clearly possible, and the definitive empirical study on default may await a micro-level data set that incorporates borrowers with FRM and ARMs, and includes data on prepayment as well as default.

[13]In 1980 the 10 year government bond rate was approximately 120 basis points below the 1 year bond rate. The yield curve was also slightly downward sloping in 1970 -- the spread between the 1 and 10 year government bond rates was approximately 30 basis points.

[14]Between 1982 and 1983, 1 year government bond rates declined approximately 570 basis points, while 10 year government bond rates declined approximately 400 basis points.

[15]Again, consistent with the previous set of simulations, there are large differences between the results of the simulations based on the two prepayment models.

REFERENCES

Boyle, P. P. (1977). "Options: A Monte Carlo Approach," Journal of Financial Economics, 4: 323-338.

Campbell, T., J. Dietrich, W. Ross, and R. Smith (1981). "The Secondary Mortgage Market in the 1980's: Structure of the Market and the Distribution of Risk," unpublished manuscript.

Campbell, T. and J. Dietrich (1983). "The Determination of Default on Insured Conventional Residential Mortgage Loans," Journal of Finance, 38: 1569-1581.

Foster, C, and R. Van Order (1984). "An Option-Based Model of Mortgage Default," Housing Finance Review, 3: 351-373.

Foster, C. and R. Van Order (1985). "FHA Terminations: A Prelude to Rational Mortgage Pricing," AREUEA Journal, 13: 273-291.

Hendershott, P. and R. Van Order (1987). "Pricing Mortgages: An Interpretation of the Models and Results," Journal of Financial Services Research, 1: 77-111.

Jackson, J. and D. Kaserman (1980). "Default Risk on Home Mortgage Loans: A Test of Competing Hypotheses," Journal of Risk and Insurance, 47: 678-690.

Lea, M. and P. Zorn (1986). "Adjustable Rate Mortgages, Economic Fluctuations, and Lender Portfolio Change," AREUEA Journal, 14: 432-447.

Manchester, J. (1985). "Evidence on Possible Default Under Three Mortgage Contracts," Housing Finance Review, 4: 517-536.

Meador, M. (1983). "The Effects on Mortgage Repayments of Restrictions on the Enforcement of Due-on-Sale Clauses: The California Experience," AREUEA Journal, 10: 465-474.

Peters, H., S. Pinkus, and D. Askin (1984a). "Figuring the Odds: A Model of Prepayment," Secondary Mortgage Market, 1: 18-23.

Peters, H., S. Pinkus, and D. Askin (1984b). "Default: The Last Resort," Secondary Mortgage Markets, 1: 16-20.

Vandell, K. (1978). "Default Risk Under Alternative Mortgage Instruments," Journal of Finance, 33: 1279-1296.

Vandell, K. (1985). "An Analysis of the Credit Risk Inherent in FNMA's Recent Portfolio Acquisitions of Adjustable Rate Mortgages," paper presented at the GAO Symposium on FNMA Issues, Washington D. C..

Vandell, K. and T. Thibodeau (1985). "Estimation of Mortgage Defaults Using Disaggregate Loan History Data," AREUEA Journal, 13: 292-316.

Waldman, M., H. Peltz, and N. Lowen (1985). "Mortgage Prepayments: The Regional Difference," Mortgage Banking, 45: 25-38.

Webb, B. (1982). "Borrower Risk Under Alternative Mortgage Instruments," Journal of Finance, 37: 169-183.

Zorn, P. and M. Lea (1989). "Mortgage Borrower Repayment Behavior: A Microeconomic Analysis with Canadian Adjustable Rate Mortgage Data," AREUEA Journal, 17: 118-136.

Appendix: Starting Values for Simulations Assessing Marginal Impacts: Expressed as Variations From the Base Case

Variables	Base Case	Simulations 1	2	3	4	5
INDEX RATE						
expected yearly rate of change	0%	-	10%	-	-	-
actual yearly rate of change	0%	-	10%	10%	-	-
expected increase in year 4	0 bp	-	-	-	300 bp	-
actual increase in year 4	0 bp	-	-	-	300 bp	300 bp
ARM DISCOUNTS AND MARGINS						
initial discount	0 bp	300 bp	-	-	-	-
ARM1 margin	200 bp	226 bp	-	-	-	-
ARM1CAP margin	200 bp	233 bp	212 bp	-	207 bp	-
ARM3 margin	200 bp	269 bp	-	-	-	-
ARM3CAP margin	200 bp	284 bp	212 bp	-	217 bp	-
INITIAL CONTRACT RATES						
FRM	9%	-	12.51%	-	10.97%	-
ARM1	9%	6.26%	9.16%	-	-	-
ARM1CAP	9%	6.33%	9.29%	-	9.07%	-
ARM3	9%	6.69%	9.54%	-	-	-
ARM3CAP	9%	6.84%	9.66%	-	9.17%	-