# Household Risk Management and Optimal Mortgage Choice

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**Abstract**

Home mortgages are the most significant financial contract for many households. The form of this contract is correspondingly important. This paper studies the choice between fixed-rate (FRM) and adjustable-rate (ARM) mortgages. In an environment with uncertain inflation, nominal FRMs have risky real capital value whereas ARMs have safe capital value. However ARMs can greatly increase the short-term variability of required real interest payments. This is a serious disadvantage of ARMs for households who face borrowing constraints and have only a small buffer stock of financial assets. The paper uses numerical methods to solve a life-cycle model with risky labor income and borrowing constraints, under alternative assumptions about available mortgage contracts. Households with large mortgages, risky labor income, high risk aversion, and a low probability of moving are more likely to prefer nominal FRMs. The paper also considers inflation-indexed FRMs. These mortgages remove the wealth risk of nominal FRMs without incurring the income risk of ARMs, and therefore are a superior vehicle for household risk management. The paper finds that the welfare gains of mortgage indexation can be very large.

# 1 Introduction

The portfolio of the typical American household is quite unlike the diversified portfolio of liquid assets discussed in finance textbooks. The major asset in the typical portfolio is a house, a relatively illiquid asset with an uncertain capital value. The value of the house typically exceeds the wealth of the household, which finances its homeownership through a mortgage contract to create a leveraged position in residential real estate. Other financial assets and liabilities are typically far less important than the house and its associated mortgage contract.

The importance of housing in household wealth is illustrated in Figure 1. This figure plots the fraction of household assets in housing and in equities against the wealth percentile of the household. Poor households appear at the left of the figure and wealthy households at the right. Data come from the 1989 and 1998 Survey of Consumer Finances. The figure shows that middle-class American families (from roughly the 40th to the 80th percentile of the wealth distribution) have more than half their assets in the form of housing. Even after the expansion of equity ownership during the 1990's, equities are of negligible importance for these households.[3]

Academic economists have explored the effects of illiquid risky housing on saving and portfolio choice (Cocco 2001, Flavin and Yamashita 1999, Goetzmann 1993, and Skinner 1994 among many others). Some have proposed innovative risk-sharing arrangements to reduce the exposure of homeowners to fluctuations in house prices (Caplin et al. 1997, Shiller 1998). In this paper we turn attention to the form of the mortgage contract, which can also have large effects on the risks faced by homeowners. We view the choice of a mortgage contract as a problem in household risk management, and we try to discover the characteristics of households that would lead them to prefer one form of mortgage over another. We abstract from all other aspects of household portfolio choice by assuming that household savings are invested entirely in riskless assets.

[3]We are grateful to Joe Tracy for providing us with this figure. The methodology used to construct it is explained in Tracy, Schneider, and Chan (1999) and Tracy and Schneider (2001). Households in the Survey of Consumer Finances are sorted by total assets, then the median share in real estate and equity is calculated separately for families in each percentile of the wealth distribution. The medians are smoothed across neighboring percentiles in the figure. Equity holdings include direct holdings as well as mutual funds, defined-contribution retirement accounts, trusts, and managed accounts. Total assets include all components of wealth except human capital and defined-benefit pension plans.

Mortgage contracts are often complex and differ along many dimensions. But they can be broadly classified into two main categories: adjustable-rate (ARM) and fixed-rate (FRM) mortgages. In this paper we study the choice between these two types of mortgages, characterizing the advantages and disadvantages of each type for different households. For realism we assume that both types of mortgages are specified in nominal terms, but we also extend our framework to consider real (inflation-indexed) mortgages of the sort proposed by Kearl (1979), Fabozzi and Modigliani (1992), and others. We include realistic refinancing provisions that give households the option to refinance their mortgages at some fixed cost.[4]

When deciding on the type of mortgage, an extremely important consideration is labor income and the risk associated with it. Labor income or human capital is undoubtedly a crucial asset for the majority of households. If markets are complete such that labor income can be capitalized and its risk insured, then labor income characteristics play no role in the mortgage decision. In practice, however, markets are seriously incomplete because moral hazard issues prevent investors from borrowing against future labor income, and insurance markets for labor income risk are not well developed.

In this paper we solve a dynamic model of the optimal consumption and mortgage choices of a finitely lived investor who is endowed with non-tradable human capital that produces a risky stream of labor income. The framework is the buffer-stock savings model of Zeldes (1989), Deaton (1991), and Carroll (1997), as extended to a life-cycle context by Cocco, Gomes, and Maenhout (1999) and Gourinchas and Parker (2001).[5] The investor initially buys a house with a required minimum downpayment, financing the rest of the purchase with either an ARM or an FRM. Subsequently the investor can refinance the FRM if it is optimal to do so. Our framework also allows the investor to take out a second loan against any housing equity in excess of the minimum downpayment. In each period there is a fixed probability that the investor

[4]The fixed cost represents some combination of explicit "points", often charged at the initiation of a mortgage contract, and implicit transactions costs (Stanton 1995). We do not allow households to choose among mortgages offering a tradeoff of points against interest rates (Stanton and Wallace 1998).

[5]Related work on portfolio choice and asset pricing in the presence of labor income includes Bodie, Merton, and Samuelson (1991), Campbell (1996), Fama and Schwert (1977), and Jagannathan and Wang (1996)—who consider tradable labor income—and Bertaut and Haliassos (1997), Campbell, Cocco, Gomes, and Maenhout (2001), Gakidis (1997), Heaton and Lucas (2000), Storesletten, Telmer, and Yaron (1998), Viceira (2001), and Vissing-Jorgensen (1999)—who consider nontradable labor income.

will move house, and we ask how this moving probability affects mortgage choice.

Our results illustrate a basic tradeoff between two types of risk. A nominal FRM, without a prepayment option, is an extremely risky contract because its real capital value is highly sensitive to inflation. The presence of a prepayment option protects the homeowner against one side of this risk, because the homeowner has the ability to call the mortgage at face value if nominal interest rates fall, and take out a new mortgage contract with a lower nominal rate. However this option does not come for free; it raises the interest rate on an FRM and leaves the homeowner with a contract that is expensive in most states of the world, but extremely cheap in states of the world with high inflation. This *wealth risk* is an important disadvantage of a nominal FRM.[6]

An ARM, on the other hand, is a safe contract in the sense that its real capital value is almost unaffected by inflation. The risk of an ARM is the *income risk* of short-term variability in the real payments that are required each month. If expected inflation and nominal interest rates increase, nominal mortgage payments increase proportionally even though the price level has not yet changed much; thus real monthly payments are highly variable. This variability would not matter if there were free borrowing against future income, but it does matter if the homeowner faces binding borrowing constraints. Constraints bind in states of the world with low income and low house prices; in these states buffer-stock savings are exhausted and home equity falls below the minimum required to take out a second loan. The danger of an ARM is that it will require higher interest payments in this situation, forcing a temporary but unpleasant reduction of consumption. We find that households with large houses relative to their income, volatile labor income, or high risk aversion are particularly adversely affected by the income risk of an ARM and are more likely to prefer an FRM.

The mobility of a household also affects the form of the optimal mortgage contract. If a homeowner knows he is highly likely to move in the near future, he is more likely to use the kind of mortgage that has the lower current interest rate. Unconditionally, this is the ARM, since the FRM has a higher yield spread that reflects the cost of the

[6]It is widely understood that rising nominal interest rates in the 1970's devastated the savings and loan industry. What is less commonly emphasized is that homeowners experienced equivalent windfall gains as inflation eroded the real value of their mortgage debts. Woodward (2001) argues that the US government implicitly subsidizes FRMs through its sponsorship of the mortgage intermediaries GNMA, FNMA, and FHLMC, thereby reducing the cost of the prepayment option to homeowners. We discuss some evidence on this point in section 2.2.

prepayment option; but if the short-term interest rate is currently high and likely to fall, it might be the FRM.

Our model also allows for variation in real interest rates, a risk that has recently been emphasized by Campbell and Viceira (2001, 2002). FRM mortgages protect homeowners against the risk that real interest rates will increase, whereas ARMs do not.

One solution to the risk management problems identified in this paper is an inflation-indexed FRM. This contract removes the wealth risk of the nominal FRM without incurring the income risk of the standard ARM contract. It greatly reduces the value of the prepayment option and thus lowers the mortgage interest rate, so an inflation-indexed FRM is cheaper than a nominal FRM in most states of the world. We calibrate our model to US interest data over the period 1962–1999 and find very large welfare gains from indexation of FRMs.

There is a large literature on mortgage choice.[7] Much of this work focuses on FRM prepayment behavior, and its implications for the pricing of mortgage-backed securities (for example Schwartz and Torous 1989 and Stanton 1995). One strand of the literature emphasizes that households know more about their moving probabilities than lenders do; this creates an adverse selection problem in prepayment that can be mitigated through the use of fixed charges or "points" at mortgage initiation (Dunn and Spatt 1985, Chari and Jagannathan 1989, Brueckner 1994, LeRoy 1996, Stanton and Wallace 1998). Alm and Follain (1984) emphasize the importance of labor income and borrowing constraints for mortgage choice, but their model is deterministic and thus they cannot address the risk management issues that are the subject of this paper. Stanton and Wallace (1999) discuss the interest-rate risk of ARMs, but without considering the role of risky labor income and borrowing constraints. We are not aware of any previous theoretical work that treats income risk and interest-rate risk within an integrated framework as we do here.

The organization of the paper is as follows. Section 2.1 lays out the model of household choice, and section 2.2 calibrates its parameters. Section 3 compares alternative nominal mortgage contracts, while section 4 studies inflation-indexed FRMs. Section 5 asks whether our results are robust to alternative parameterizations. Section 6 concludes.

[7] Follain (1990) surveys the literature from the 1980's and earlier.

# 2 A Life-Cycle Model of Mortgage Choice

## 2.1 Model specification

*Time parameters and preferences*

We model the consumption and asset choices of a household with a time horizon of $T$ periods. We study the decision of how to finance the purchase of a house of a given size $\overline{H}$. That is, we assume that buying a house is strictly preferred to renting—perhaps because of tax considerations—so that we do not model the decision to buy versus rent. In addition, we do not study what determines the size of the house the household wishes to buy.[8]

In each period $t$, $t = 1, ..., T$, the household chooses consumption of all goods other than housing, $C_t$. The date $t$ nominal price of consumption is denoted by $P_t$. We assume preference separability between housing and consumption. Since the size of the house and the utility derived from it are fixed, we can omit housing from the objective function of the household and write:

$$\max_{C_t} E_0 \sum_{t=0}^{T} \beta^t \frac{C_t^{1-\gamma}}{1-\gamma} + \beta^{T+1} \frac{W_{T+1}^{1-\gamma}}{1-\gamma}, \tag{1}$$

where $\beta$ is the time discount factor and $\gamma$ is the coefficient of relative risk aversion. The household derives utility from terminal real wealth, $W_{T+1}$, which can be interpreted as the remaining lifetime utility from reaching age $T+1$ with wealth $W_{T+1}$.

*The term structure of nominal and real interest rates*

FRM and ARM mortgages differ because nominal interest rates are variable over time. This variability comes from movements in both the expected inflation rate and the ex ante real interest rate. We use the simplest model that captures variability in both these components of the short-term nominal interest rate, and allows for some

[8]Cocco (2001) explores this issue using a life-cycle model similar to the one in this paper.

predictability of interest rate movements. Thus in our model there will be periods when homeowners can rationally anticipate declining or increasing short-term nominal interest rates, and thus declining or increasing ARM payments.

We assume that expected inflation follows an AR(1) process. That is, log one-period expected inflation, $\pi_{1t} = \log(1 + \Pi_{1t})$, follows the process:

$$\pi_{1t} = \mu(1 - \phi) + \phi\pi_{1,t-1} + \epsilon_t, \tag{2}$$

where $\epsilon_t$ is a normally distributed white noise shock with mean zero and variance $\sigma_\epsilon^2$. By contrast, we assume that the ex ante real interest rate is variable but serially uncorrelated. The expected log real return on a one-period bond, $r_{1t} = \log(1 + R_{1t})$, is given by:

$$r_{1t} = \overline{r} + \psi_t, \tag{3}$$

where $\overline{r}$ is the mean log real interest rate and $\psi_t$ is a normally distributed white noise shock with mean zero and variance $\sigma_\psi^2$.

We make the assumption that real interest rate risk is transitory for tractability. Fama (1975) showed that the assumption of a constant real interest rate was a good approximation for US data in the 1950's and 1960's, but it is well known that more recent US data display serially correlated movements in real interest rates (see for example Garcia and Perron 1996, Gray 1996, or Campbell and Viceira 2001). However movements in expected inflation are the most important influence on long-term nominal interest rates (Fama 1990, Mishkin 1990, Campbell and Ammer 1993), and our AR(1) assumption for expected inflation allows persistent variation in nominal interest rates.

The log yield on a one-period nominal bond, $y_{1t} = \log(1 + Y_{1t})$, is equal to the log real return on a one-period bond plus expected inflation plus a constant risk premium, $\zeta$:

$$y_{1t} = r_{1t} + \pi_{1t} + \zeta. \tag{4}$$

To model long-term nominal interest rates, we assume that the log pure expectations hypothesis holds.[9] That is, we assume that the log yield on a long-term $n$-period nominal bond is equal to the expected sum of successive log yields on one-period nominal bonds which are rolled over for $n$ periods:

$$y_{nt} = (1/n) \sum_{i=0}^{n-1} E_t[y_{1,t+i}]. \tag{5}$$

This model implies that excess returns on long-term bonds over short-term bonds are unpredictable, even though changes in nominal short rates are partially predictable. Thus there are no predictably good or bad times to own short-term or long-term bonds, and homeowners cannot reduce their average borrowing costs by trying to time the bond market.

To simplify the model, we abstract from one-period uncertainty in realized inflation; thus we assume that the realized log real return on a one-period bond is equal to the expected real interest rate. While clearly counterfactual, this assumption should have very little effect on our conclusions about mortgage choice, since short-term inflation uncertainty is quite modest and affects ARMs and FRMs symmetrically.

*Available mortgage contracts*

At date one, the household finances the purchase of a house of size $\overline{H}$ with a nominal loan of $(1-\lambda)P_1^H\overline{H}$, where $\lambda$ is the required down-payment and $P_1^H$ is the date one nominal price of housing. The mortgage loan is assumed to have maturity $T$, so that it is paid off by period $T+1$.

If the household chooses a FRM, and the date one interest rate on a FRM with maturity $T$ is $Y_{T,1}^F$, then in each subsequent period the household must make a real mortgage payment, $M_t^F$, of:

$$M_t^F = \frac{(1-\lambda)P_1^H\overline{H}}{P_t \sum_{j=1}^{T}(1+Y_{T,1}^F)^{-j}}. \tag{6}$$

Since nominal mortgage payments are fixed at mortgage initiation, real payments are inversely proportional to the price level $P_t$. This implies that a nominal FRM,

[9] For a textbook exposition and summary of the empirical evidence on this model, see Campbell, Lo, and MacKinlay (1997), Chapter 10.

without a prepayment option, is a risky contract because its real capital value is highly sensitive to inflation.

We allow for a prepayment option. A household that chooses an FRM may in later periods refinance at a monetary cost of $\rho$. Let $I_t^\rho$ be an indicator variable which takes the value of one if the household refinances in period $t$, and zero otherwise. We assume that a refinancing household at date $t$ obtains a new FRM mortgage with maturity $T-t+1$ such that by the terminal date $T+1$ the mortgage will have been paid down.

We assume that the date $t$ nominal interest rate on a FRM is given by:

$$Y_{T-t+1,t}^F = Y_{T-t+1,t} + \theta^F, \tag{7}$$

where $\theta^F$ is a constant mortgage premium over the yield on a $(T-t+1)$-period bond. This premium compensates the mortgage lender for default risk and for the value of the refinancing option.

If the household chooses an ARM, the annual real mortgage payment, $M_t^A$, is given by the following. We write $D_t$ for the nominal principal amount of the original loan outstanding at date $t$. Then the date $t$ real mortgage payment is given by:

$$M_t^A = \frac{Y_{1,t}^A D_t + \Delta D_{t+1}}{P_t}, \tag{8}$$

where $\Delta D_{t+1}$ is the component of the mortgage payment at date $t$ that goes to pay down principal rather than pay interest. We assume that $\Delta D_{t+1}$ is equal to the average nominal loan reduction that occurs at date $t$ in a FRM for the same initial loan. While this does not correspond exactly to a conventional ARM, it greatly simplifies the problem since by having loan reductions that depend only on time and the amount borrowed, the proportion of the original loan that has been repaid is not a state variable.

The date $t$ nominal interest rate on an ARM is assumed to be equal to the short rate plus a constant premium:

$$Y_{1,t}^A = Y_{1,t} + \theta^A. \tag{9}$$

The ARM mortgage premium $\theta^A$ compensates the mortgage lender for default risk.

Finally, we have to specify what happens in case the household cannot meet mortgage payments and is forced to default. We assume that the household is left with a certain lower bound of lifetime utility. We will study how our results are affected by this lower bound.

*Labor income risk*

The household is endowed with stochastic gross real labor income in each period, $L_t$, which cannot be traded or used as collateral for a loan. As usual we use a lower case letter to denote the natural log of the variable, i.e., $l_t \equiv \log(L_t)$. Household $j$'s age $t$ real labor income is exogenous and is given by:

$$l_{jt} = f(t, Z_{jt}) + v_{jt} + \omega_{jt}, \tag{10}$$

where $f(t, Z_{jt})$ is a deterministic function of age $t$ and other individual characteristics $Z_{jt}$, and $v_{jt}$ and $\omega_{jt}$ are stochastic components of income. Thus log income is the sum of a deterministic component that can be calibrated to capture the hump shape of earnings over the life-cycle, and two random components, one transitory and one persistent. The transitory component is captured by the shock $\omega_{jt}$, an i.i.d. normally distributed random variable with mean zero and variance $\sigma_\omega^2$. The persistent component is assumed to be entirely permanent; it is captured by the process $v_{jt}$, which is assumed to follow a random walk:

$$v_{jt} = v_{j,t-1} + \eta_{jt}, \tag{11}$$

where $\eta_{jt}$ is an i.i.d. normally distributed random variable with mean zero and variance $\sigma_\eta^2$.

This model for income is a simplified version of Cocco, Gomes, and Maenhout (1999). That paper assumes that the temporary component of income is idiosyncratic, while the permanent component includes both idiosyncratic and aggregate terms; this implies that the random component of aggregate labor income follows a random walk as assumed by Fama and Schwert (1977) and Jagannathan and Wang (1996). Here we do not need to separately measure the aggregate and idiosyncratic components of permanent income shocks.

*Taxation*

We model the tax code in the simplest possible way, by considering a linear taxation rule. Gross labor income, $L_t$, is taxed at the constant tax rate $\tau$. We also allow for mortgage interest deductibility at this rate.

*House prices and second loans*

The price of housing fluctuates over time. Let $p_{jt}^H$ denote the date $t$ real log price of house $j$. Real house price growth is given by

$$\Delta p_{jt}^H = g + \delta_{jt}, \tag{12}$$

a constant $g$ plus an i.i.d. normally distributed shock $\delta_{jt}$ with mean zero and variance $\sigma_\delta^2$. To economize on state variables we assume that innovations to a household's real house price are perfectly positively correlated with innovations to the permanent component of the household's real labor income so that

$$\delta_{jt} = \alpha \eta_{jt}, \tag{13}$$

where $\alpha > 0$. This assumption implies that states with low house prices are also states with low permanent labor income; in these states an increase in required mortgage payments under an ARM contract can require costly adjustments in consumption. In the next section we use PSID data to judge the plausibility of this assumption.[10]

House prices matter in our model because we allow households who have accumulated housing equity to obtain a second one-period loan. Recall that $D_t$ is the nominal dollar amount of the original loan outstanding at date $t$. We allow households at time $t$ to borrow $B_t$ nominal dollars for one period subject to the constraint

$$B_t \leq (1 - \lambda) P_t^H \overline{H} - D_t. \tag{14}$$

[10] A large positive correlation between income shocks and house prices is also present in Ortalo-Magné and Rady (2001).

That is, total borrowing cannot exceed the original proportion of house value that could be borrowed at date one. We assume that the nominal interest rate on the second loan is equal to $Y_{1t}$ plus a constant premium, $\theta^B$.

*Moving*

We introduce moving in the model in the following simple manner: with probability $p$ the household moves in each period. When this happens the household sells the house, pays off the remaining mortgage, and evaluates utility of wealth using the terminal utility function. This enables us to study the impact of the likelihood of moving, or of termination of the mortgage contract, on mortgage choice.

*Summary of the household's optimization problem*

In summary, the household's control variables are $\{C_t, B_t, I_t^\rho\}_{t=1}^T$. The problem is somewhat simpler in the case of an ARM, because in this case the refinancing indicator variable $I_t^\rho$ is not a control variable. The vector of state variables can be written as $X_t = \left\{t, y_{1t}, W_t, P_t, y_{1,t'}, t', v_t\right\}_{t=1}^T$, where $y_{1,t'}$ $(t' < t)$ is the level of nominal interest rates when the mortgage was initiated or was last refinanced, $t'$ is the period when the mortgage was initiated or was last refinanced, $W_t$ is real liquid wealth or cash-on-hand, $P_t$ is the date $t$ price level, and $v_t$ is date $t$ aggregate labor income.

The equation describing the evolution of real cash-on-hand (when $B_t$ is equal to zero and there is no refinancing at period $t$) can be written as

$$W_{t+1} = (W_t - C_t - (1-\tau)M_t)(1 + R_{1,t+1}) + (1-\tau)L_{t+1}. \tag{15}$$

*Solution technique*

This problem cannot be solved analytically. Given the finite nature of the problem a solution exists and can be obtained by backward induction. We discretize the state space and the choice variables using equally spaced grids in the log scale. The density functions for the random variables were approximated using Gaussian quadrature methods to perform numerical integration (Tauchen and Hussey 1991). The nominal interest rate process was approximated by a two-state transition probability matrix. The grid points for these processes were chosen using Gaussian quadrature. In period $T+1$ the utility function coincides with the value function. In every period $t$ prior to $T+1$, and for each admissible combination of the state variables, we compute the value associated with each combination of the choice variables. This value is equal to current utility plus the expected discounted continuation value. To compute this continuation value for points which do not lie on the grid we use cubic spline interpolation. The combinations of the choice variables ruled out by the constraints of the problem are given a very large (negative) utility such that they are never optimal. We optimize over the different choices using grid search.

## 2.2 Parameterization

We study the optimal consumption and mortgage choices of investors who buy a house early in life. That is, adult age in our model starts at age 26 and we let $T$ be equal to 30 years. For computational tractability, we let each period in our model correspond to two years but we report annualized parameters and data moments for ease of interpretation. In the baseline case we assume an annual discount factor $\beta$ equal to 0.98 and a coefficient of relative risk aversion $\gamma$ equal to three. We will study how the degree of risk aversion affects mortgage choice.

*Inflation and interest rates*

Parameter estimates for inflation and interest rates are reported in Table 1. Our measure of inflation is the consumer price index. We use annual data from 1962 to 1999, time aggregated to two-year periods, to estimate equation (2). We find average inflation of 4.6% per year, with a standard deviation of 3.9%, and an annual autoregressive coefficient of 0.569. To measure the log real interest rate we deflate the two-year nominal interest rate using the consumer price index. We measure the variability of the ex-ante real interest rate by regressing ex post two-year real returns on lagged two-year real returns and two-year nominal interest rates, and then calculating the variability of the fitted value. We obtain a standard deviation of 2.2% per year, as compared with a mean of 2.0%. This standard deviation is surprisingly high, which may be a result of overfitting in our regression; but since our assumption that all real interest rate risk is transitory artificially diminishes the importance of such risk, we use this high standard deviation to partially offset this effect.[11]

*Mortgage contracts and second loans*

Two important parameters of the mortgage contracts are the mortgage premiums, $\theta^F$ and $\theta^A$. It is natural to assume that $\theta^F \geq \theta^A$. One can think of $\theta^A$ as a pure measure of default risk, while $\theta^F$ contains both default risk and the value of the prepayment option.

To estimate the mortgage premium on FRM contracts, $\theta^F$, we compute the difference between interest rates on commitments for fixed-rate 30 year mortgages and the yield to maturity on 30-year treasury bonds. The FRM data were obtained from the Federal Home Loan Mortgage Corporation (FHLMC) for the sample period 1977 to 2000. The average annual difference over this period is 1.62%.

To estimate the mortgage premium on ARM contracts, $\theta^A$, we use data from the monthly interest rate survey of the Federal Housing Finance Board (FHFB). These are monthly national averages of ARM rates, with an average term to maturity of 28/29 years. The sample period is shorter, from January 1986 to December 1999. The average difference between the ARM contract rate and the yield on a 1-year bond is equal to 1.44%.

The difference between the ARM and FRM premiums is surprisingly small. This may result in part from measurement error in the survey data or the short sample period of the survey. It may also result from the liquidity of the FRM market which has been supported by US government guarantees over many decades, particularly through the government's agency GNMA ("Ginnie Mae") and the private but goverment-sponsored entities FNMA ("Fannie Mae") and FHLMC ("Freddie Mac").[12]

[11]We have also obtained results for a smaller standard deviation of 1.8%, and our results remain essentially unaffected.

[12]Woodward (2001) describes in detail how federal policy has supported the FRM market. Several studies have found important liquidity effects in mortgage markets. Cotterman and Pearce (1996) find a 25-40 basis point spread between private label mortgages and the conforming mortgages that are securitized by FNMA and FHLMC, while Black, Garbade, and Silber (1981) and Rothberg, Nothaft, and Gabriel (1989) find that the initial securitization of mortgages by GNMA lowered mortgage interest rates by 60-80 basis points.

In order to place ARM and FRM mortgages on a more equal footing within the context of our model, we reduce the annual ARM premium to 1% in our benchmark case.

In the baseline case we set $\theta^B$ to $\infty$ and therefore do not allow the homeowner to take out a second loan. We relax this restriction in section 5.

*House prices*

We use house price data from the PSID for the years 1970 through 1992. As with income the self assessed value of the house was deflated using the Consumer Price Index, with 1992 as the base year, to obtain real house prices. We drop observations for households who reported that they moved in the previous two years since the house price reported does not correspond to the same house. In order to deal with measurement error we drop the observations in the top and bottom five percent of real house price changes.

We estimate the average real growth rate of house prices and the standard deviation of innovations to this growth rate. Over the sample period real house prices grew an average of 0.9% per year. Part of this increase is due to improvements in the quality of houses, which cannot be separated from other reasons for house price appreciation using PSID data. The annualized standard deviation of house price changes is 11.5%, a value comparable to those reported by Case and Shiller (1989) and Poterba (1991).

*Labor income*

To estimate the income process, we follow Cocco, Gomes, and Maenhout (1999). We use the family questionnaire of the Panel Study on Income Dynamics (PSID) to estimate labor income as a function of age and other characteristics. In order to obtain a random sample, we drop families that are part of the Survey of Economic Opportunities subsample. Only households with a male head are used, as the age profile of income may differ across male- and female-headed households, and relatively few observations are available for female-headed households. Retirees, nonrespondents, students, and homemakers are also eliminated from the sample.

Like Cocco, Gomes, and Maenhout (1999) and Storesletten, Telmer, and Yaron (1998), we use a broad definition of labor income so as to implicitly allow for insurance mechanisms—other than asset accumulation—that households use to protect themselves against pure labor income risk. Labor income is defined as total reported labor income plus unemployment compensation, workers compensation, social security, supplemental social security, other welfare, child support and total transfers (mainly help from relatives), all this for both head of household and if present his spouse. Observations which still reported zero for this broad income category were dropped.

Labor income defined this way is deflated using the Consumer Price Index, with 1992 as the base year. The estimation controls for family-specific fixed effects. The function $f(t, Z_{jt})$ is assumed to be additively separable in $t$ and $Z_{jt}$. The vector $Z_{jt}$ of personal characteristics, other than age and the fixed household effect, includes marital status, household composition, and the education of the head of the household.[13] Figure 2 shows the fit of a third order polynomial to the estimated age dummies, which is the two-year labor income profile we use to parameterize the model.

The residuals obtained from the fixed-effects regressions of (log) labor income on $f(t, Z_{jt})$ can be used to estimate $\sigma_\eta^2$ and $\sigma_\omega^2$. Define $Y_{jt}^*$ as:

$$\log(Y_{jt}^*) \equiv \log(Y_{jt}) - \widehat{f}(t, Z_{jt}). \tag{16}$$

Equation (10) implies that

$$\log(Y_{jt}^*) = v_{jt} + \omega_{jt} \tag{17}$$

Taking first differences:

$$\log(Y_{jt}^*) - \log(Y_{j,t-1}^*) = v_{jt} - v_{j,t-1} + \omega_{jt} - \omega_{j,t-1} = \eta_{jt} + \omega_{jt} - \omega_{j,t-1}. \tag{18}$$

[13]Campbell, Cocco, Gomes, and Maenhout (2001) estimate separate age profiles for different educational groups. They also estimate different income processes for households whose heads are employed in different industries, or self-employed. In this version of the paper, we focus on a single representative income process for simplicity.

One approach to calibration is to use the standard deviation of income innovations from (18), and the correlation between innovations to income and real house price growth, to obtain estimates for the standard deviations of $\eta_{jt}$ and $\omega_{jt}$. The estimated correlation is 0.027, with a p-value of 2%. Recall that in the model, and for tractability, we have assumed that real house price growth is perfectly positively correlated with innovations to the persistent component of income, and has zero correlation with purely transitory shocks. This assumption, and the standard deviation of $\eta_{jt} + \omega_{jt} - \omega_{j,t-1}$, imply annualized estimates for $\sigma_\eta$ and $\sigma_\omega$ of 0.35% and 16.3%, respectively.

This estimate of $\sigma_\eta$, the standard deviation of permanent income shocks, seems too low. The reason is probably that measurement error biases our estimate of the correlation between house price and income growth downwards. Therefore we use an alternative approach to pick parameters for the benchmark case. The persistence of aggregate labor income suggests that transitory labor income shocks are purely idiosyncratic. If this is the case, then $\sigma_\eta$ can be estimated as in Cocco, Gomes, and Maenhout (1999) by averaging across all individuals in our sample and taking the standard deviation of the growth rate of average income. Following this procedure we estimate $\sigma_\eta$ equal to 2.0%. We set $\sigma_\omega$ equal to 14.1% (20% over two years), which implies a correlation of house price growth with total income growth of about 0.1. Given the somewhat arbitrary nature of these decisions, we are careful to do sensitivity analysis with respect to the income growth parameters.

*Taxation*

The PSID contains information on total estimated federal income taxes of the household. We use this variable to obtain an estimate of $\tau$. Dividing total federal taxes by our broad measure of labor income and computing the average across households, we obtain an average tax rate of 10.3%. This number underestimates the effect of taxation because the PSID does not contain information on state taxes, and because our model abstracts from the progressivity of the income tax. To roughly compensate for these biases we set $\tau$ equal to 20%. All the calibrated parameters are summarized in Table 2.

# 3 Alternative Nominal Mortgages

We now use our model to compare the welfare implications of fixed and adjustable rate nominal mortgages. We do so by calculating lifetime expected utilities under alternative FRM and ARM contracts. As a first step in this analysis, Figure 3 shows various percentiles of the distribution of realized lifetime utility, based on simulation of the model across one thousand households. Each household is assumed to have to finance a \$150,000 home using either an ARM, or an FRM with a \$1,000 refinancing cost, or an FRM with a \$100,000 (effectively infinite) refinancing cost.

Figure 3 shows that it is only those investors in the bottom part of the utility distribution who are worse off with an ARM than with a FRM. These results reflect the chief disadvantage of an ARM, the cash-flow risk that ARM payments will rise suddenly, exhausting bufferstock savings and forcing an extremely unpleasant cutback in consumption. The possibility of a forced reduction in consumption leads investors under an ARM to save more and consume less early in life. This is illustrated in Table 3, which shows that average consumption growth is higher under an ARM than a FRM.

Table 4 shows the average welfare gain of the FRM relative to the ARM in the form of standard consumption-equivalent variations. We calculate an average by weighting each state by its ergodic or steady-state probability. For each mortgage contract we compute the constant consumption stream that makes the household as well off in expected utility terms. Utility losses are then obtained by measuring the change in this equivalent consumption stream across mortgage contracts. With a \$150,000 home, investors are on average 2.3% better off with an FRM that allows cheap refinancing, and they are 1.0% better off with an FRM that effectively prohibits refinancing. This welfare gain reflects the appropriate probability-weighted average of small welfare losses in most states of the world, and an extremely large welfare gain in bad states of the world, as illustrated in Figure 3.

By comparing welfare levels across FRMs with alternative refinancing costs, we can obtain the value of the option to refinance which in this baseline case is equal to 1.3% of consumption. In the presence of transaction costs for refinancing, a household's refinancing decision depends on the size of the benefits from refinancing. Figure 4 shows the cumulative proportion of investors who choose to refinance in the baseline case. When the remaining horizon gets short enough, investors find it optimal not to pay the refinancing cost because they can realize only limited interest savings by refinancing the modest remaining loan.

*Cash-flow and labor income risk*

In order to understand how cash-flow risk affects optimal mortgage choice, we now consider a smaller $100,000 house with correspondingly lower mortgage payments. Figure 5 shows that in this case investors above the first percentile of the welfare distribution are better off with an ARM than with a FRM. This result can be interpreted as follows. As we previously argued, the disadvantage of an ARM is the cash-flow risk that the ARM payments will rise suddenly, exhausting bufferstock savings and forcing a reduction in consumption. This risk is greater when the house size is larger. For a small house, the wealth stability provided by the ARM outweighs the cash-flow risk. This is also reflected in Table 4; for a smaller house investors are on average 2.9% worse off with a FRM than an ARM.

Labor income risk affects mortgage choice in a very similar manner. From the budget constraint we see that the risk of an increase in mortgage payments is closely related to the risk of a drop in labor income. In the presence of borrowing constraints either event can force a costly reduction in consumption. Figure 6 shows the welfare distribution for a $150,000 house with a lower 3.5% standard deviation of labor income shocks (5% standard deviation over two years). Just as in the case of a small house, investors are on average better off with an ARM than with a FRM. The mean welfare gain of an ARM relative to an FRM is 0.9% of annual consumption in this low-income-risk scenario.

Investors are particularly sensitive to these risks when their risk aversion is high. This point is illustrated graphically in Figure 7, which sets risk aversion $\gamma = 5$ and shows an enormous ARM welfare loss in particularly bad states of the world. Table 4 shows that conservative investors lose the equivalent of one third of their consumption if they are exposed to the risk of an ARM.

For symmetry, Table 4 also reports results for lower risk aversion, larger house size, and greater income risk (24.8% standard deviation, or 35% over two years). Finally, the table shows the value of the option to refinance for these different parameterizations. Although the value of the FRM relative to the ARM varies substantially with labor income risk and risk aversion, the value of the option to refinance is fairly insensitive to these parameters. Instead the value of the refinancing option is determined largely by house size, since the refinancing cost is assumed fixed while the refinancing benefit is proportional to interest savings.

*Moving probability*

We have also solved our model assuming a moving probability equal to 0.10, meaning that the household moves on average once every ten years. Recall that in all the cases reported in Table 4, the probability of moving is equal to zero. We find that the welfare gain of an FRM over an ARM is lower when the moving probability is higher. In the baseline case of Table 4 the average welfare gain of a refinanceable FRM relative to an ARM is 2.3% of annual consumption, whereas when this moving probability is positive the corresponding value is only 1.4%. If a homeowner knows he is highly likely to move in the near future, he is more likely to use the kind of mortgage that has the lower current interest rate. On average, this is the ARM since the FRM has a higher yield spread that reflects the cost of the prepayment option.

# 4 Inflation-Indexed Mortgages

In this section we investigate the welfare properties of inflation-indexed mortgages. In principle an inflation-indexed FRM can offer the wealth stability of an ARM, together with the income stability of an FRM; it should therefore be a superior vehicle for household risk management.

We consider inflation-indexed FRM contracts in which the interest rate is fixed in real terms. We study the welfare properties of a standard inflation-indexed FRM contract, with fixed real mortgage payments, and also those of an inflation-indexed mortgage whose real payments diminish at the average rate of inflation. We do so because our investor is borrowing constrained; one of the advantages of the standard inflation-indexed FRM contract, relative to the nominal FRM and ARM contracts, is that real payments are lower early in life, when borrowing constraints are more severe. This is an important advantage of the standard inflation-indexed contract, but is separate from the risksharing advantages of indexation. Thus, to obtain a pure measure of the risksharing advantages of indexation we consider an inflation-indexed mortgage whose real payments diminish at the average rate of inflation.

If the household chooses an inflation-indexed FRM with fixed real payments, and the current real interest rate on an inflation-indexed FRM contract with maturity $T$ is $R^I_{T,1}$, then in each subsequent period the household must make a real mortgage payment, $M^I_t$, of:

$$M^I_t = \frac{(1-\lambda)P^H_1\overline{H}}{\sum_{j=1}^{T}(1+R^I_{T,1})^{-j}}. \tag{19}$$

Real mortgage payments are fixed at mortgage initiation, and nominal payments increase in proportion to the price level $P_t$. Thus, unlike a nominal FRM, the real capital value of an inflation-indexed mortgage is not sensitive to inflation.

For the inflation-indexed mortgage contract we ignore the possibility of refinancing. Given our assumption that real interest rate variation is transitory, the gains from refinancing in our model would be fairly small, and even a small monetary refinancing cost would prevent households from exercising their option. In reality, even with persistent real interest rates, the possibility of refinancing an inflation-indexed contract is likely to be only a minor feature of the contract, given the low volatility of the real interest rate compared with that of nominal yields.

We assume that the date $t$ real interest rate on an inflation-indexed FRM is given by:

$$R^I_{T-t+1,t} = R_{T-t+1,t} + \theta^I, \tag{20}$$

where $\theta^I$ is a constant mortgage premium over the yield on a $(T - t + 1)$-period real bond. Since we do not allow for the possibility of refinancing the inflation-indexed FRM contract we set $\theta^I$ equal to 1% in annual terms (which is also the ARM premium). This premium compensates the mortgage lender for default risk.

In the inflation-indexed mortgage with real payments which diminish at the average rate of inflation we have that:

$$M^D_t = \frac{M^D_{t-1}}{1+\mu}, \tag{21}$$

where $M^D_t$ is the date $t$ real mortgage payment and $\mu$ is average inflation. The interest rate or internal rate of return for this mortgage contract is assumed to be equal to that for the standard inflation-indexed FRM.

Figure 8 shows the various percentiles of the welfare distribution of realized lifetime utility for the standard inflation-indexed FRM contract and the one with declining real payments, for the benchmark parameters. For comparison, this figure also shows the results for the nominal ARM and FRM that were illustrated in Figure 3. This figure shows that the welfare gains of inflation-indexed mortgages are substantial. The gains are particularly large for households in the bottom percentiles, but there are benefits to households across the welfare distribution.

The standard inflation-indexed mortgage offers the wealth stability of an ARM, together with the income stability of the FRM. In addition it relaxes borrowing constraints, since real mortgage payments are lower than in the nominal FRM and ARM early in life, when borrowing constraints are more severe. A measure of the degree to which investors are borrowing constrained is consumption growth. Table 5 shows that in the benchmark case the average consumption growth rate under the indexed contract with fixed real payments is only 0.8% compared to 2.5% and 3% for the nominal FRM and ARM, respectively. Households are also able to smooth consumption better with the inflation-indexed contract, as reflected in the lower variability of consumption growth.

Table 6 shows the average welfare gains of the inflation-indexed mortgages relative to the ARM in the form of standard consumption-equivalent variations. For completeness the earlier comparison of the nominal FRM with the ARM is repeated here. The welfare gains of the standard inflation-indexed mortgage are large, particularly for households who face large cash-flow risk (with larger houses and correspondingly higher mortgage payments relative to labor income), large labor income risk, and who are more risk averse. The average welfare gains are as high as two-thirds of annual consumption for investors with risk aversion of five and for those who finance a house of two hundred thousand dollars. These are also the households who on average are better off with a nominal FRM than an ARM, and are more affected by the income risk of an ARM.

Comparing the two inflation-indexed contracts, we see that the average welfare gains of the contract with declining real mortgage payments are roughly half of those of the mortgage contract with fixed real payments, but are also large. For example, in the benchmark case of $\gamma$ equal to 3 and house size of \$150,000 Table 6 shows that investors are on average 9.6% better off with a declining inflation-indexed FRM than with an ARM, and a comparison of the first and third columns of Table 6 shows that they are 7.3% better off than with a nominal FRM. These gains are even larger for more conservative investors and those investors who face higher cash-flow risk, either because of larger mortgage payments relative to labor income or because of higher labor income risk.

These results imply that with substantial inflation risk of the sort we have estimated for the 1962–1999 period, the risksharing advantages of indexation are very large. Households would be able to manage their lifetime risks much more effectively if they had access to inflation-indexed mortgage contracts. Of course, these results depend on the parameters we have estimated. Clarida, Gali, and Gertler (2000) and Campbell and Viceira (2001) report considerably lower inflation risk during the period since 1983 in which Federal Reserve Chairmen Paul Volcker and Alan Greenspan have brought US inflation under control. In the next section we assess the benefits of mortgage indexation for alternative parameterizations, including an interest-rate process characteristic of the US in the recent period of Volcker-Greenspan monetary policy.

# 5 Alternative Parameterizations

*The Volcker-Greenspan monetary policy period*

We assess the benefits of mortgage indexation when we calibrate our interest-rate process to a process characteristic of the US in the 1983-1999 period. As expected, the estimated parameters (shown in the footnote to Table 7) imply considerably lower inflation risk since 1983, both in terms of the standard deviation of log inflation and the persistence of the shocks. The recent data also imply lower variability in real interest rates.

Table 7 compares nominal and inflation-indexed FRMs with ARMs over the 1983-1999 period. The first column shows that nominal FRMs are less attractive relative to ARMs than was the case in our benchmark model. However inflation-indexed FRMs remain superior instruments for risk management. Comparing Table 7 with Table 6, we see that the welfare gains of indexation in the Volcker-Greenspan period are substantially lower than those that we obtained for the 1962–1999 period. Even in the recent environment of low inflation risk, however, the welfare gains of indexation are as high as fifteen percent of annual consumption for more conservative investors, and one-fifth to one-third of annual consumption for those investors who face high cash-flow risk.

*Second loans*

We now study how allowing homeowners to take out second loans, if they have positive home equity, affects the benefits of mortgage indexation. Table 8 shows the welfare gains for a second loan premium, $\theta^B$, of 1 percent in annual terms. For tractability, in this table we eliminate the prepayment option on the nominal FRM.

Comparing Tables 8 and 6 we see that the benefits of indexation are smaller when second loans are allowed, since the potential to take out second loans mitigates the income risk that we have estimated for ARM mortgages. However second loans do not eliminate income risk altogether, because low house prices may coincide with low income and high inflation, in which case second loans are unavailable precisely when they would be most valuable. Thus our basic results survive the addition of second loans to our model.

*Consumption in default*

Our results are sensitive to the assumption that we make about consumption in the event of a mortgage default. In the benchmark case we assume that default leads to a lifetime non-housing consumption stream of $1,000 per year. Table 9 assumes instead that default triggers a consumption stream that is 50% of its average value under the baseline parameterization. We interpret these different lower bounds on consumption as roughly capturing the effects of different exemption levels in the event of personal bankruptcy. Comparing Tables 9 and 6, we see that a higher default level of consumption makes a nominal FRM less attractive relative to an ARM, because it mitigates the income risk of the ARM. The benefits of FRM indexation are also reduced but remain substantial. These results suggest that in states where bankruptcy is relatively cheaper one should observe, *ceteris paribus*, a higher proportion of households choosing ARMs.

*Impatient households*

In panel A of Table 10 we consider impatient investors with a smaller time discount factor. Such investors strongly prefer FRMs; since they accumulate a smaller buffer-stock of liquid financial assets they are less able to cope with the income risk of ARMs. Also, they benefit greatly from the postponed payments of an inflation-indexed FRM with constant real payments.

*ARM cap and floor*

In panel B of Table 10 we consider a hybrid ARM in which there is a floor and a cap on the nominal ARM interest rate equal to the unconditional mean ARM rate plus and minus 3%, or plus and minus 4%. The hybrid ARM is more attractive than either a straight ARM or a nominal FRM, as it mitigates income risk while still limiting wealth risk. The benefits of mortgage indexation are smaller in comparison to a hybrid ARM, but remain substantial.

*Correlation of income and interest rates*

Our benchmark model assumes that shocks to income growth are uncorrelated with shocks to real interest rates. If we assume instead that income growth is negatively correlated with real interest rates, this exacerbates the income risk of ARMs, since income will tend to be low precisely when interest rates are high and required ARM mortgage payments are high. Panel C of Table 10 shows that in this case nominal and inflation-indexed FRMs become more attractive relative to ARMs.

*Refinancing from an ARM to a FRM*

Finally, we consider an alternative specification in which we allow households who choose a nominal ARM to subsequently refinance into a nominal FRM. Recall that our baseline specification compares a nominal ARM to a nominal FRM, without allowing households to switch between the two. In practice, and even though there are transaction costs associated with switching between different types of mortgages, it is possible to do so. The degree of complexity of our model prevents us from modelling the decision to, in every period, switch to another type of mortgage. However, we can study the welfare effects of allowing a one time switch from a nominal ARM to a nominal FRM. It may be the case that ARM borrowers find it optimal to choose the ARM when interest rates are low, but plan to switch to a FRM if and when interest rates increase.

The solution to this alternative specification requires that at each date $t$, and for each combination of the state variables, we compare the utility of remaining an ARM borrower to the utility of switching to the FRM contract. More precisely, let $V_t(X_t; FRM)$ denote the lifetime utility of becoming an FRM borrower at date $t$, when the vector of state variables is given by $X_t$. Assuming a zero switching cost, the household will at date $t$ switch to the FRM if and only if $V_t(X_t; FRM) > V_t(X_t; ARM)$, where $V_t(X_t; ARM)$ is the lifetime utility of remaining an ARM borrower with the option to switch to the FRM in a subsequent period.

To solve for the optimal mortgage choices under this alternative specification, we set the parameters equal to their benchmark values and the switching cost to zero. For these parameters most borrowers prefer an ARM and never switch to a FRM. There are 5.6% of households who start off with an ARM and later on switch to a FRM. They do so when current interest rates are high. However, not all households find it optimal to switch to the FRM when current rates are high; only those with low current income and financial wealth do so. The intuition for this result is simple: when current interest rates are high the ARM implies a larger current mortgage payment than the FRM. Those consumers who are more borrowing constrained find it optimal to pay the higher average premium on the FRM in exchange for the lower current mortgage payments. This result illustrates once more the importance of borrowing constraints for mortgage choice. As consumers grow older the labor income profile becomes flatter and households become less borrowing constrained. For this reason the benefits of switching to the FRM contract are lower. This explains our finding that for the baseline parameters all the switching from the ARM to the FRM takes place before age 38.

We also study the welfare effects of allowing consumers to switch from the ARM to the FRM. As before we compute the mean welfare gain delivered by the ARM with the option to switch to the FRM, relative to the baseline nominal ARM contract. The welfare gain is 3.1%.

## 6 Conclusion

The problem of mortgage choice is both basic and complex. It is basic because almost every middle-class American faces this choice at least once in his or her life. It is complex because it involves many considerations that are at the frontier of finance theory: uncertainty in inflation and interest rates, borrowing constraints, illiquid assets, uninsurable risk in labor income, and the need to plan over a long horizon.

Despite the complexity of the problem, it is important for financial economists to try to offer scientifically grounded advice. If financial economists avoid the topic, homeowners may be guided by unwise commercial or journalistic advice; for example they may be urged to time the bond market by predicting the direction of long-term interest rates. Mortgage choice should not be left to specialists in real estate, but should be treated as an aspect of household risk management, a topic that lies at the heart of finance.

In this paper we have shown that the form of the mortgage contract can have large effects on household welfare. We begin by comparing the standard nominal ARM and FRM contracts. FRM contracts expose households to wealth risk, while ARM contracts expose them to income risk: the risk that borrowing constraints will bind more severely when high interest rates coincide with low income and house prices. While the exact levels of welfare depend on the particular premia we have assumed for ARM and FRM mortgages, we can draw general conclusions about the types of households that should be more likely to use ARMs. Households with smaller houses relative to income, more stable income, lower risk aversion, more lenient treatment in bankruptcy, and a higher probability of moving should be the households that find ARMs most attractive.

Interestingly, these results match quite well with empirical evidence reported by Shilling, Dhillon, and Sirmans (1987). These authors look at micro data on mortgage borrowing and estimate a reduced-form econometric model of mortgage choice. They find that households with co-borrowers and married couples (whose household income is presumably more stable) and households with a higher moving probability are more likely to use ARMs.

We have also investigated the welfare properties of innovative inflation-indexed mortgage contracts. An inflation-indexed FRM can offer the wealth stability of an ARM together with the income stability of an FRM, so it is a superior vehicle for household risk management. Using US data from the period 1962–1999 we find very large welfare gains from the availability of an inflation-indexed mortgage contract. The welfare gains of indexation are lower but still substantial if we calibrate our interest-rate process to the period since 1983 in which there has been lower inflation risk, and if we allow homeowners who have accumulated positive home equity to take out second loans.

The concept of income risk that we emphasize in this paper has interesting implications for other areas of finance. Corporations, for example, must consider the risk that short-term or floating-rate debt will require high interest payments in circumstances where internal cash flow and collateral are low and external financing is expensive. Here as in the problem of mortgage choice, borrowing constraints both complicate and enrich standard models of risk management.

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Table 1: Estimated parameters of the interest rate process

| Description | Parameter | Value |
|---|---|---|
| Mean log inflation | $\mu$ | .046 |
| S.d. of log inflation | $\sigma(\pi_{1t})$ | .039 |
| Autoregression parameter | $\phi$ | .569 |
| Mean log real yield | $\overline{r}$ | .020 |
| S.d. of real log yield | $\sigma(r_{1t})$ | .022 |

All parameters are in annual terms. The interest rate measure is the one-year Treasury bond rate from 1962 to 1999.

Table 2: Calibrated parameters

| Description | Parameter | Value |
|---|---|---|
| Risk aversion | $\gamma$ | 3 |
| Discount factor | $\beta$ | .98 |
| House size | $\overline{H}$ | $150,000 |
| Downpayment | $\lambda$ | 0 |
| Tax rate | $\tau$ | .20 |
| FRM premium | $\theta^F$ | .016 |
| Refinancing cost | $\rho$ | $1,000 |
| ARM premium | $\theta^A$ | .010 |
| Second loan premium | $\theta^B$ | $\infty$ |
| Mean real house price growth | $exp(g + \sigma_\delta^2/2)$ | .009 |
| S.d. of log real house price growth | $\sigma_\delta$ | .115 |
| S.d. of transitory income shocks | $\sigma_\omega$ | .141 |
| S.d. of persistent income shocks | $\sigma_\eta$ | .020 |

All parameters are in annual terms. The income and house price data are from the PSID from 1970 through 1992. Families that were part of the Survey of Economic Opportunities were dropped from the sample. Labor income in each year is defined as total reported labor income plus unemployment compensation, workers compensation, social security, supplemental social security, other welfare, child support, and total transfers, all this for both head of household and if present his spouse. Labor income and house prices were deflated using the Consumer Price Index to obtain real variables. House prices are the reported house prices by the families in PSID data.

Table 3: Consumption growth with alternative nominal mortgage contracts

| | FRM | | ARM | |
|---|---|---|---|---|
| | $\overline{\Delta c_t}$ | $\sigma(\Delta c_t)$ | $\overline{\Delta c_t}$ | $\sigma(\Delta c_t)$ |
| $\gamma = 1/2$ | .021 | .235 | .025 | .224 |
| $\gamma = 3$ | .025 | .175 | .030 | .173 |
| $\gamma = 5$ | .027 | .163 | .032 | .163 |
| $\overline{H} = 100$ | .017 | .142 | .020 | .131 |
| $\overline{H} = 150$ | .025 | .175 | .030 | .173 |
| $\overline{H} = 200$ | .041 | .234 | .053 | .243 |
| $\sigma_\omega = .035$ | .020 | .090 | .024 | .114 |
| $\sigma_\omega = .141$ | .025 | .175 | .030 | .173 |
| $\sigma_\omega = .248$ | .036 | .214 | .045 | .221 |

This table shows average annual consumption growth, for goods other than housing, and the standard deviation of annual consumption growth under different mortgage contracts and for different parameter configurations. The data are obtained by simulating the model in section 2. Annual average consumption growth and the standard deviation of annual consumption growth are obtained by dividing the two-year values by two and square root of two, respectively. The FRM contract allows for refinancing at a $1,000 cost.

Table 4: Average welfare gains of nominal FRMs over ARMs

| | FRM | | Refinancing |
|---|---|---|---|
| | $\rho = \$1,000$ | $\rho = \$100,000$ | Option |
| $\gamma = 1/2$ | -3.62% | -4.54% | 0.92% |
| $\gamma = 3$ | 2.27% | 1.00% | 1.27% |
| $\gamma = 5$ | 34.63% | 32.74% | 1.89% |
| $\overline{H} = 100$ | -2.88% | -3.45% | 0.57% |
| $\overline{H} = 150$ | 2.27% | 1.00% | 1.27% |
| $\overline{H} = 200$ | 14.51% | 11.32% | 3.19% |
| $\sigma_\omega = .035$ | -0.87% | -2.02% | 1.15% |
| $\sigma_\omega = .141$ | 2.27% | 1.00% | 1.27% |
| $\sigma_\omega = .248$ | 15.47% | 13.83% | 1.65% |

This table shows the mean welfare gain delivered by an FRM, with two alternative refinancing costs, relative to an ARM. The data are obtained by simulating the model in section 2. Welfare is reported in the form of standard consumption-equivalent variations. We weight the different states by the ergodic or steady-state distribution. For each mortgage contract we compute the constant consumption stream that makes the household as well off in expected utility terms. Utility losses are then obtained by measuring the change in this equivalent consumption stream across mortgage contracts. The last column shows the value of the option to refinance for the different parameterizations obtained as the welfare difference for the $\rho = \$100,000$ and $\rho = \$1,000$ scenarios.

Table 5: Consumption growth with inflation-indexed mortgage contracts

| | Indexed Constant | | Indexed Declining | |
|---|---|---|---|---|
| | $\overline{\Delta c_t}$ | $\sigma(\Delta c_t)$ | $\overline{\Delta c_t}$ | $\sigma(\Delta c_t)$ |
| $\gamma = 1/2$ | .016 | .108 | .026 | .142 |
| $\gamma = 3$ | .008 | .133 | .024 | .163 |
| $\gamma = 5$ | .009 | .124 | .025 | .155 |
| $\overline{H} = 100$ | .008 | .115 | .017 | .133 |
| $\overline{H} = 150$ | .008 | .133 | .024 | .163 |
| $\overline{H} = 200$ | .008 | .158 | .035 | .212 |
| $\sigma_\omega = .035$ | .002 | .076 | .019 | .083 |
| $\sigma_\omega = .141$ | .008 | .133 | .024 | .163 |
| $\sigma_\omega = .248$ | .016 | .162 | .033 | .202 |

This table shows average annual consumption growth, for goods other than housing, and the standard deviation of annual consumption growth under different mortgage contracts and for different parameter configurations. The data are obtained by simulating the model in section 2. Annual average consumption growth and the standard deviation of annual consumption growth are obtained by dividing the two-year values by two and square root of two, respectively.

Table 6: Average welfare gains of nominal and inflation-indexed FRMs over ARMs

| | Nominal | Inflation-Indexed FRM | |
|---|---|---|---|
| | FRM | Constant | Declining |
| $\gamma = 1/2$ | -3.62% | 0.59% | 0.23% |
| $\gamma = 3$ | 2.27% | 18.50% | 9.58% |
| $\gamma = 5$ | 34.63% | 68.14% | 47.49% |
| $\overline{H} = 100$ | -2.88% | 4.67% | 1.46% |
| $\overline{H} = 150$ | 2.27% | 18.50% | 9.58% |
| $\overline{H} = 200$ | 14.51% | 66.07% | 34.59% |
| $\sigma_\omega = .035$ | -0.87% | 10.96% | 5.31% |
| $\sigma_\omega = .141$ | 2.27% | 18.50% | 9.58% |
| $\sigma_\omega = .248$ | 15.47% | 46.75% | 26.31% |

This table shows the mean welfare gain delivered by a nominal FRM and by an inflation-indexed FRM, with constant real payments and with real payments which diminish at the average rate of inflation, relative to an ARM. The data are obtained by simulating the model in sections 2 and 4. Welfare is reported in the form of standard consumption-equivalent variations. We weight the different states by the ergodic or steady-state distribution. For each mortgage contract we compute the constant consumption stream that makes the household as well off in expected utility terms. Utility losses are then obtained by measuring the change in this equivalent consumption stream across mortgage contracts.

Table 7: Average welfare gains of nominal and inflation-indexed FRMs over ARMs in the 1983-1999 period

| | Nominal | Inflation-Indexed FRM | |
|---|---|---|---|
| | FRM | Constant | Declining |
| $\gamma = 1/2$ | -3.96% | 0.34% | 0.13% |
| $\gamma = 3$ | -3.47% | 7.14% | 2.16% |
| $\gamma = 5$ | -1.03% | 15.95% | 6.73% |
| $\overline{H} = 100$ | -3.83% | 2.14% | 0.38% |
| $\overline{H} = 150$ | -3.47% | 7.14% | 2.16% |
| $\overline{H} = 200$ | 0.12% | 31.48% | 7.90% |
| $\sigma_\omega = .035$ | -3.80% | 3.98% | 1.63% |
| $\sigma_\omega = .141$ | -3.47% | 7.14% | 2.16% |
| $\sigma_\omega = .248$ | -3.29% | 19.38% | 6.30% |

This table shows the mean welfare gain delivered by a nominal FRM and by an inflation-indexed FRM, with constant real payments and with real payments which diminish at the average rate of inflation, relative to an ARM . The data are obtained by simulating the model in sections 2 and 4. The parameters of the inflation and real interest rate processes are calibrated using data for the 1983-1999 period. The annual parameters are: mean log inflation ($\mu$) equal to .034, standard deviation of log inflation ($\sigma(\pi_{1t})$) equal to .012, autoregression parameter ($\phi$) equal to 0.412, mean log real yield ($\overline{r}$) equal to .031, and standard deviation of log real yield ($\sigma(r_{1t})$) equal to .016. Welfare is reported in the form of standard consumption-equivalent variations. We weight the different states by the ergodic or steady-state distribution. For each mortgage contract we compute the constant consumption stream that makes the household as well off in expected utility terms. Utility losses are then obtained by measuring the change in this equivalent consumption stream across mortgage contracts.

Table 8: Average welfare gains of nominal FRM without the option to refinance and inflation-indexed FRMs over ARMs when second loans are allowed

| | Nominal | Inflation-Indexed FRM | |
|---|---|---|---|
| | FRM | Constant | Declining |
| $\gamma = 1/2$ | -18.03% | 0.48% | 0.19% |
| $\gamma = 3$ | -2.36% | 11.38% | 4.33% |
| $\gamma = 5$ | 7.91% | 26.22% | 13.24% |
| $\overline{H} = 100$ | -7.94% | 3.36% | 0.71% |
| $\overline{H} = 150$ | -2.36% | 11.38% | 4.33% |
| $\overline{H} = 200$ | 7.34% | 60.87% | 31.81% |
| $\sigma_\omega = .035$ | -6.37% | 7.74% | 3.21% |
| $\sigma_\omega = .141$ | -2.36% | 11.38% | 4.33% |
| $\sigma_\omega = .248$ | -0.13% | 36.46% | 19.86% |

This table shows the mean welfare gain delivered by a nominal FRM without the option to refinance and by an inflation-indexed FRM, with constant real payments and with real payments which diminish at the average rate of inflation, relative to an ARM. The data are obtained by simulating the model in sections 2 and 4. We allow homeowners to take out second loans if they have positive home equity. The second loan premium is set equal to .01 in annual terms. Welfare is reported in the form of standard consumption-equivalent variations. We weight the different states by the ergodic or steady-state distribution. For each mortgage contract we compute the constant consumption stream that makes the household as well off in expected utility terms. Utility losses are then obtained by measuring the change in this equivalent consumption stream across mortgage contracts.

Table 9: Average welfare gains of nominal FRM and inflation-indexed FRMs over ARMs for a larger lower bound on consumption

| | Nominal | Inflation-Indexed FRM | |
|---|---|---|---|
| | FRM | Constant | Declining |
| $\gamma = 1/2$ | -3.81% | 0.45% | 0.04% |
| $\gamma = 3$ | -3.10% | 11.48% | 3.10% |
| $\gamma = 5$ | 1.99% | 25.61% | 10.20% |
| $\overline{H} = 100$ | -3.12% | 4.46% | 1.21% |
| $\overline{H} = 150$ | -3.10% | 11.48% | 3.10% |
| $\overline{H} = 200$ | -2.24% | 26.76% | 6.52% |
| $\sigma_\omega = .035$ | -1.57% | 10.18% | 4.56% |
| $\sigma_\omega = .141$ | -3.10% | 11.48% | 3.10% |
| $\sigma_\omega = .248$ | -3.64% | 14.73% | 1.34% |

This table shows the mean welfare gain delivered by a nominal FRM and by an inflation-indexed FRM, with constant real payments and with real payments which diminish at the average rate of inflation, relative to an ARM. The data are obtained by simulating the model in sections 2 and 4, with a larger lower bound on real annual consumption, equal to 50% of the average real realized consumption under the baseline parameterizarion. Welfare is reported in the form of standard consumption-equivalent variations. We weight the different states by the ergodic or steady-state distribution. For each mortgage contract we compute the constant consumption stream that makes the household as well off in expected utility terms. Utility losses are then obtained by measuring the change in this equivalent consumption stream across mortgage contracts.

Table 10: Average welfare gains of nominal FRM and inflation-indexed FRMs over ARMs for different parameterizations

| Panel A | Nominal | Inflation-Indexed FRM | |
|---|---|---|---|
| Disc. Factor | FRM | Constant | Declining |
| $\beta = 0.98$ | 2.27% | 18.50% | 9.58% |
| $\beta = 0.94$ | 3.73% | 28.11% | 11.79% |
| $\beta = 0.90$ | 5.22% | 36.83% | 13.89% |
| Panel B | Nominal | Inflation-Indexed FRM | |
| $[floor, cap]$ | FRM | Constant | Declining |
| $[-\infty, +\infty]$ | 2.27% | 18.50% | 9.58% |
| $[-4\%, +4\%]$ | -1.49% | 14.37% | 5.54% |
| $[-3\%, +3\%]$ | -4.04% | 11.19% | 2.81% |
| Panel C | Nominal | Inflation-Indexed FRM | |
| Correlation | FRM | Constant | Declining |
| 0.00 | 2.27% | 18.50% | 9.58% |
| $-0.10$ | 3.58% | 19.99% | 10.96% |
| $-0.20$ | 4.36% | 20.87% | 11.80% |

This table shows the mean welfare gain delivered by a nominal FRM and by an inflation-indexed FRM, with constant real payments and with real payments which diminish at the average rate of inflation, relative to an ARM. The data are obtained by simulating the model in sections 2 and 4. Panel A shows the results for different values of the annual discount factor. Panel B shows the results for hybrid ARMs characterized by a cap and a floor in the nominal interest rate paid by homeowners. The cap and floor are set equal to plus and minus 4 (and 3) percentage points of the mean nominal ARM rate, respectively. Panel C shows the results for different values for the correlation between the real interest rate shock and and the real labor income/house price shock. All other parameters are the baseline parameters shown in tables 1 and 2. Welfare is reported in the form of standard consumption-equivalent variations. We weight the different states by the ergodic or steady-state distribution. For each mortgage contract we compute the constant consumption stream that makes the household as well off in expected utility terms. Utility losses are then obtained by measuring the change in this equivalent consumption stream across mortgage contracts.

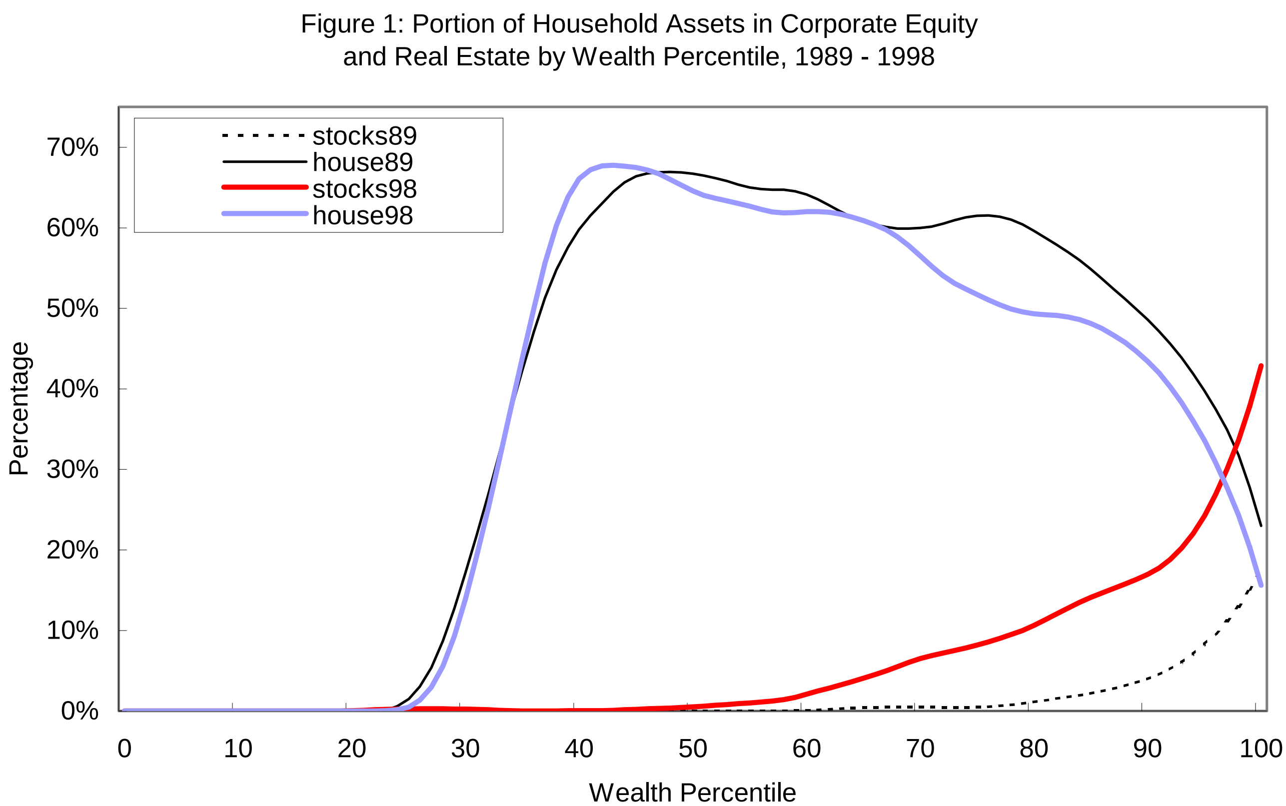


Figure 1: Portion of Household Assets in Corporate Equity and Real Estate by Wealth Percentile, 1989 and 1998. The data are from the 1989 and 1998 Survey of Consumer Finances. We would like to thank Joe Tracy for kindly providing us the data for this figure.

Figure 2: Two-year labor income profile.

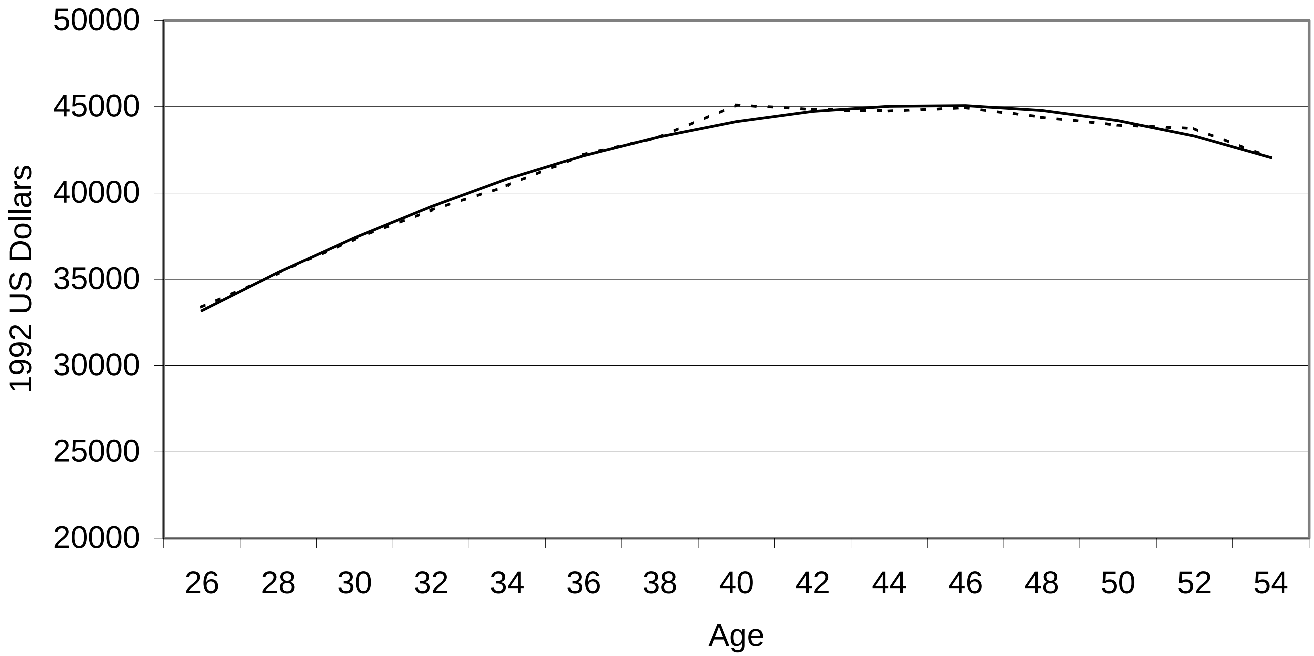


Figure 2: Two-year labor income profile. This figure shows estimated age dummies and a fitted third-order polynomial. The data are from the PSID for the years 1970 through 1992. We use a broad definition of labor income, defined as total reported labor income plus unemployment compensation, workers compensation, social security, supplemental social security, other welfare, child support and total transfers (mainly help from relatives), all this for both head of household and if present his spouse. Observations which still reported zero for this broad income category were dropped. In order to obtain a random sample we dropped families that are part of the Survey of Economic Opportunities subsample.

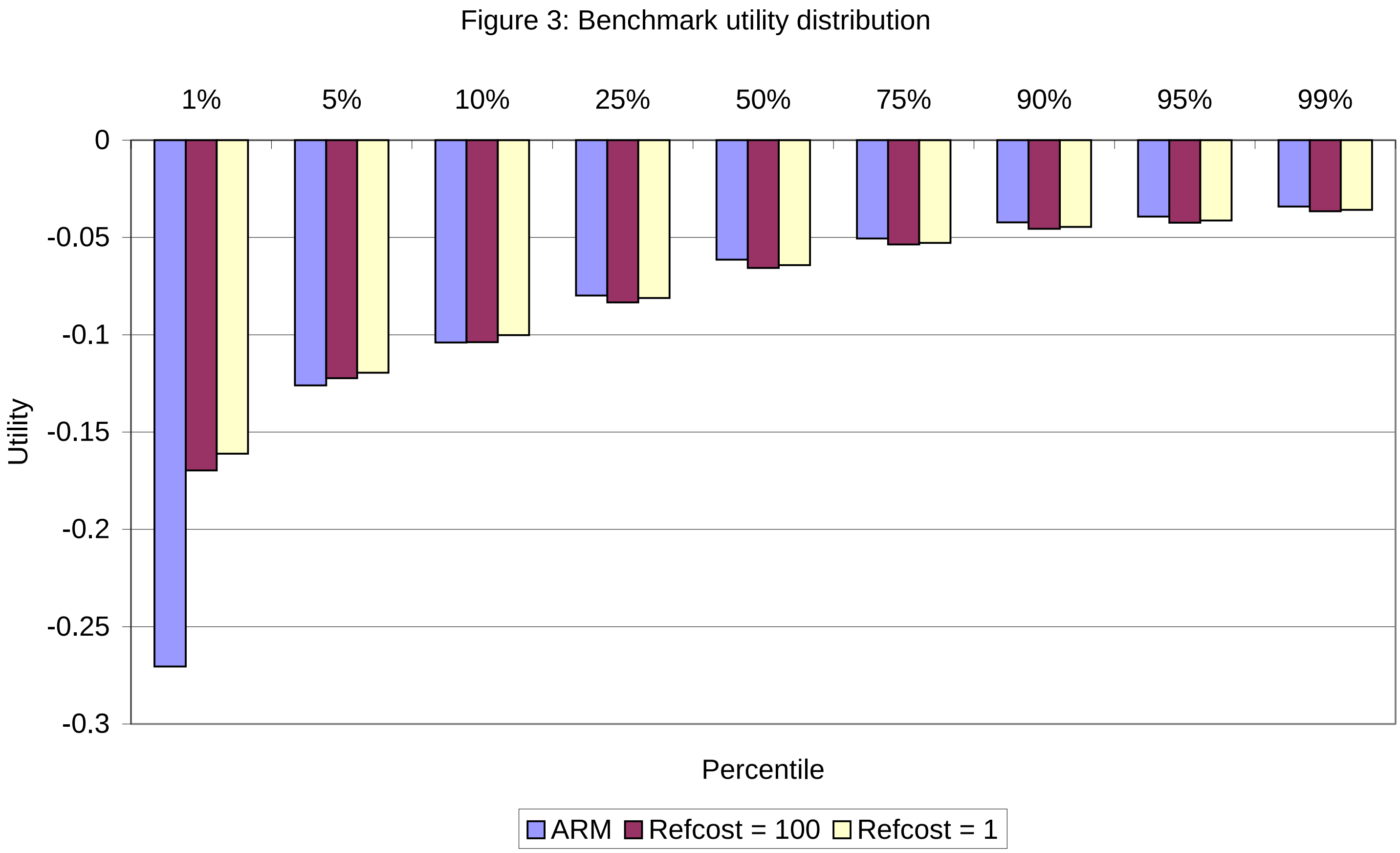


Figure 3: Benchmark utility distribution. This figure shows various percentiles of the distribution of realized utility when we simulate the model for 1,000 households. The parameters of the model are given in Tables 1 and 2, with the size of the house that needs to be financed equal to $150,000. The figure illustrates utility for an ARM and for FRMs with refinancing costs of $1,000 and $100,000 (which effectively prohibits refinancing).

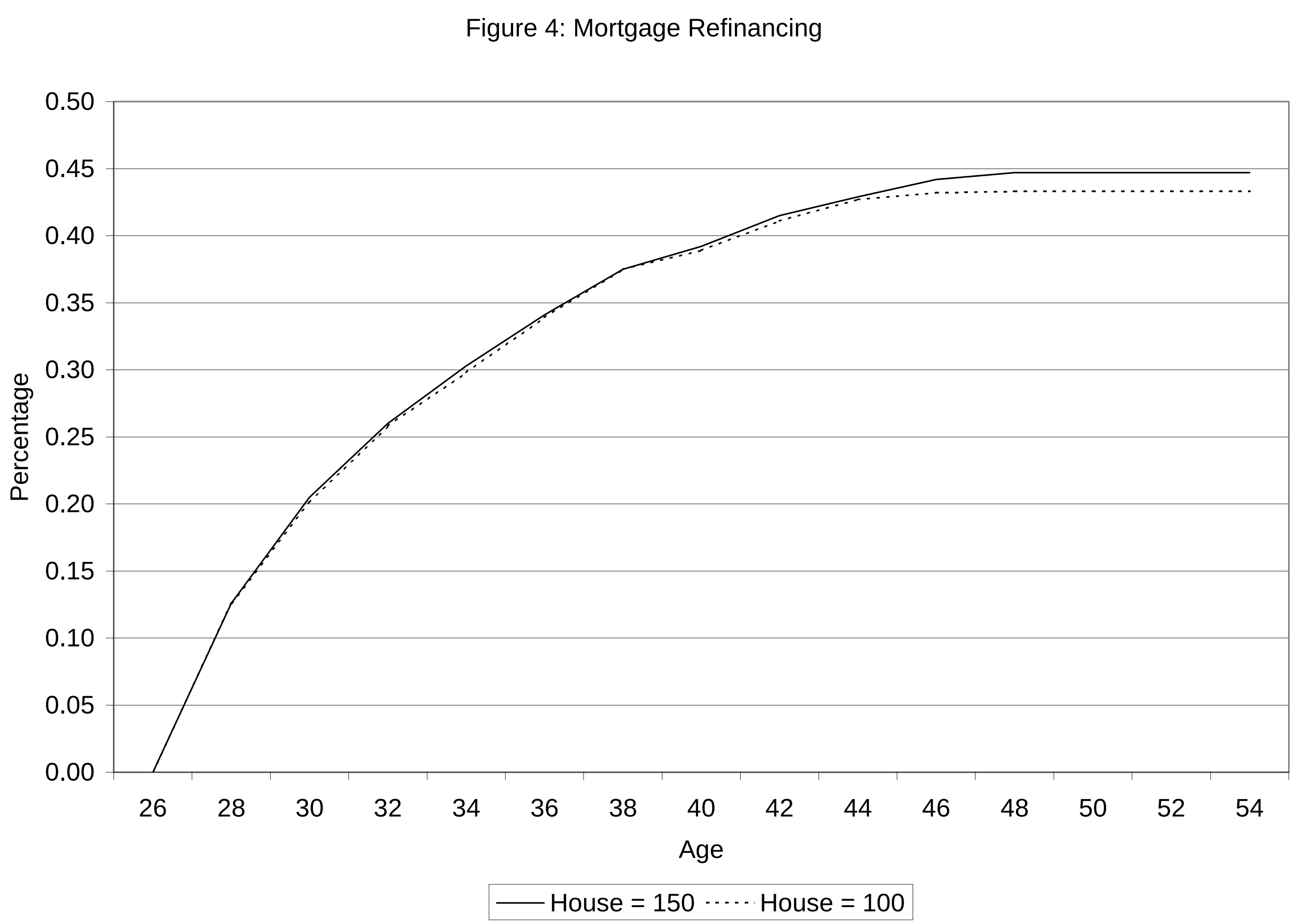


Figure 4: Mortgage refinancing. This figure shows the cumulative proportion of investors who choose to refinance FRM mortgages on houses worth $150,000 and $100,000. The parameters of the model are given in Tables 1 and 2, with a refinancing cost of $1,000.

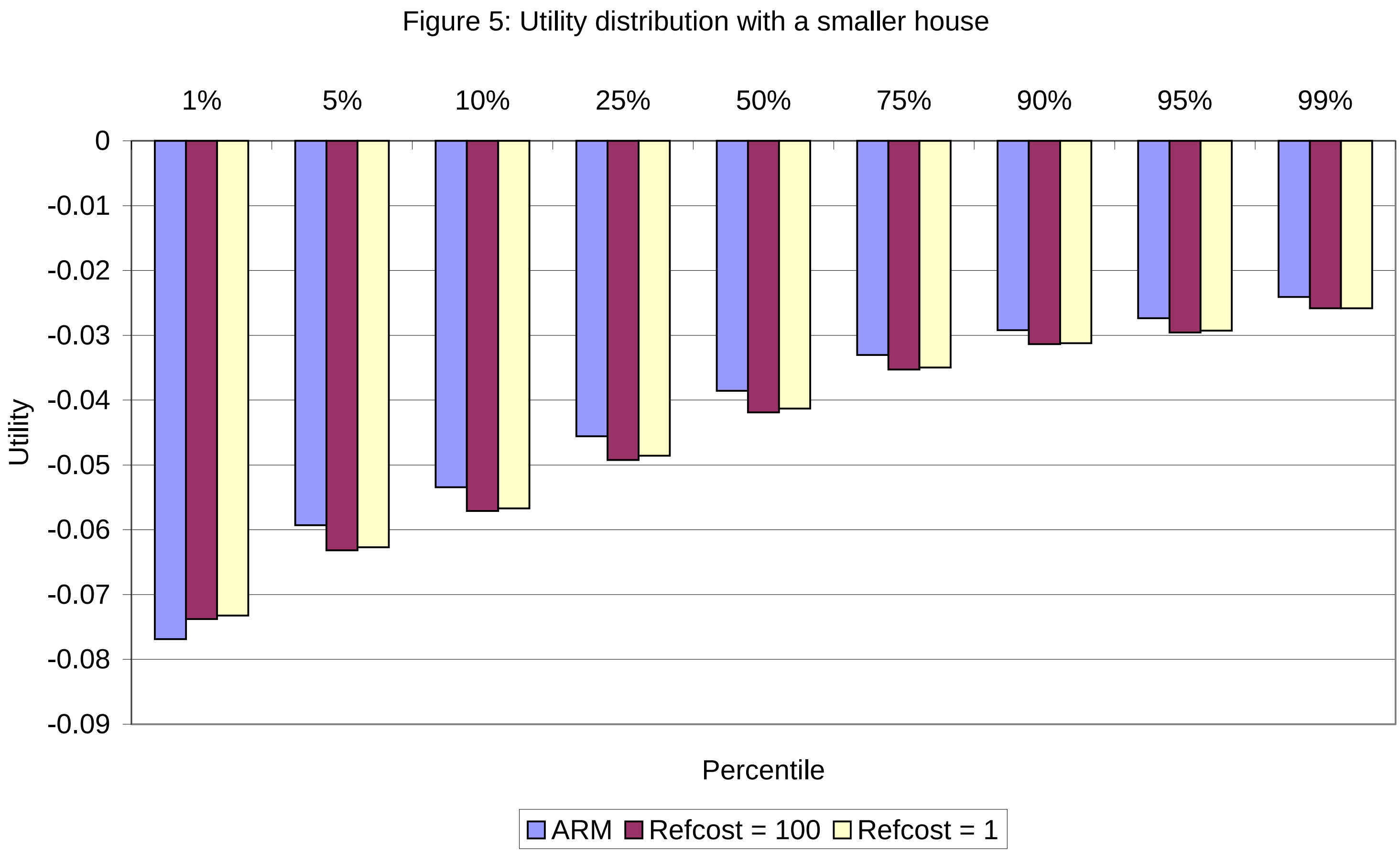


Figure 5: Utility distribution with a smaller house. This figure shows various percentiles of the distribution of realized utility when we simulate the model for 1,000 households. The parameters of the model are given in Tables 1 and 2, with the size of the house that needs to be financed equal to $100,000. The figure illustrates utility for an ARM and for an FRM with a refinancing cost of $1,000 and $100,000 (which effectively prohibits refinancing).

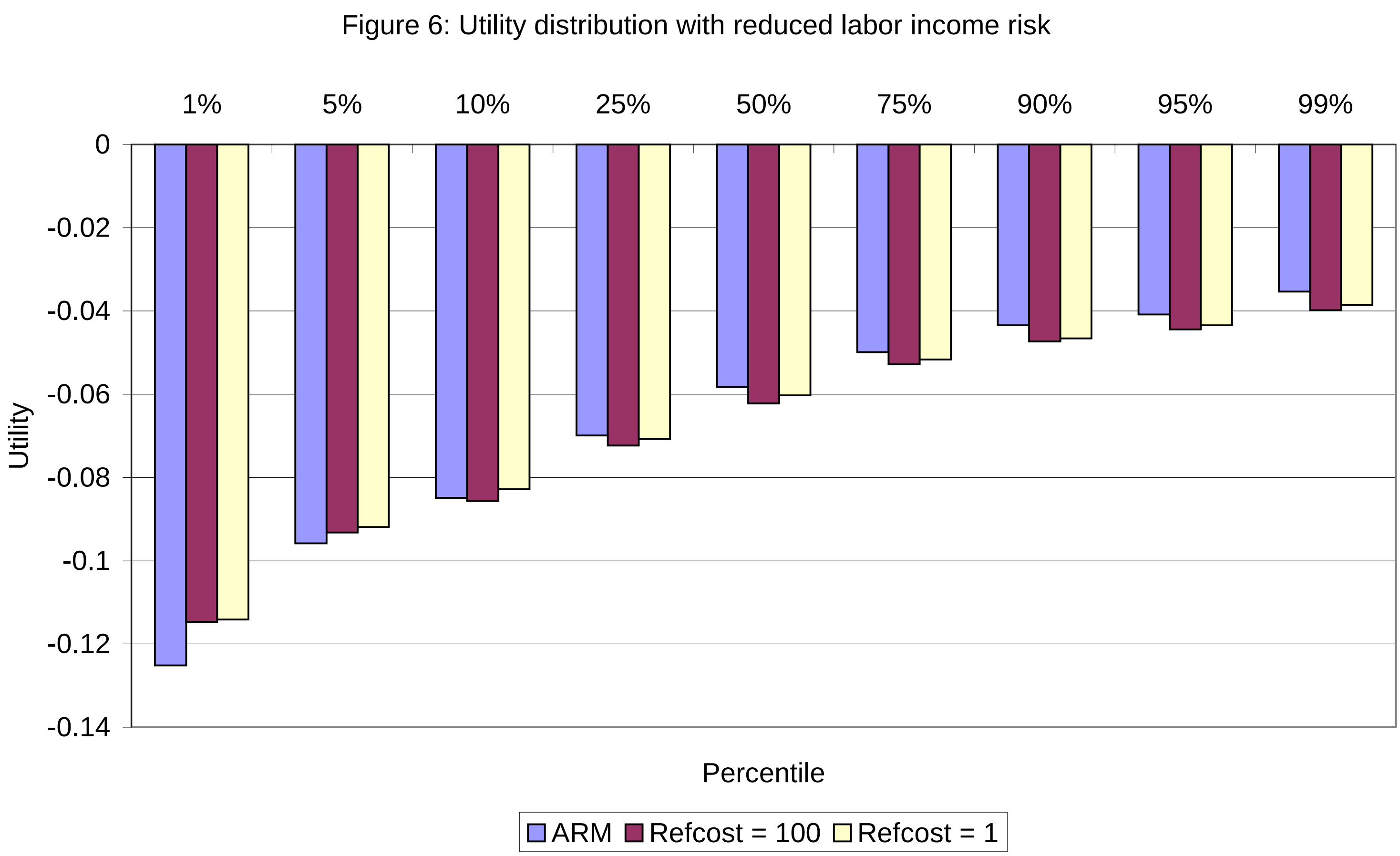


Figure 6: Utility distribution with reduced labor income risk. This figure shows various percentiles of the distribution of realized utility when we simulate the model for 1,000 households. The parameters of the model are given in Tables 1 and 2, with house size equal to \$150,000 and the standard deviation of temporary labor income shocks reduced to 0.035 in annual terms. The figure illustrates utility for an ARM and for an FRM with a refinancing cost of \$1,000 and \$100,000 (which effectively prohibits refinancing).

Figure 7: Utility distribution with increased risk aversion

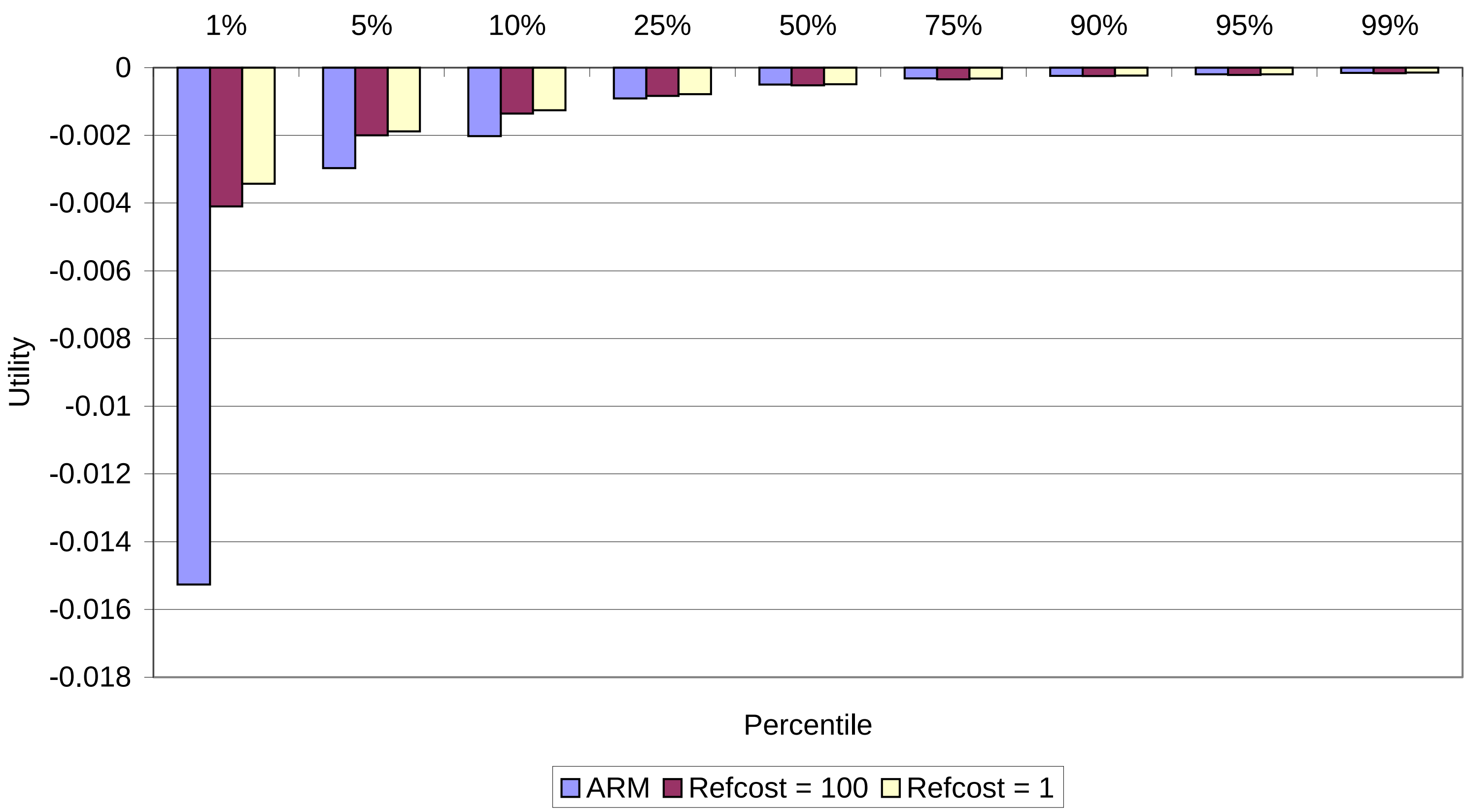


Figure 7: Utility distribution with increased risk aversion. This figure shows various percentiles of the distribution of realized utility when we simulate the model for 1,000 households. The parameters of the model are given in Tables 1 and 2, with a house size of $150,000 and higher risk aversion of 5. The figure illustrates utility for an ARM and for an FRM with a refinancing cost of $1,000 and $100,000 (which effectively prohibits refinancing).

Figure 8: Utility distribution with nominal and inflation-indexed mortgage contracts

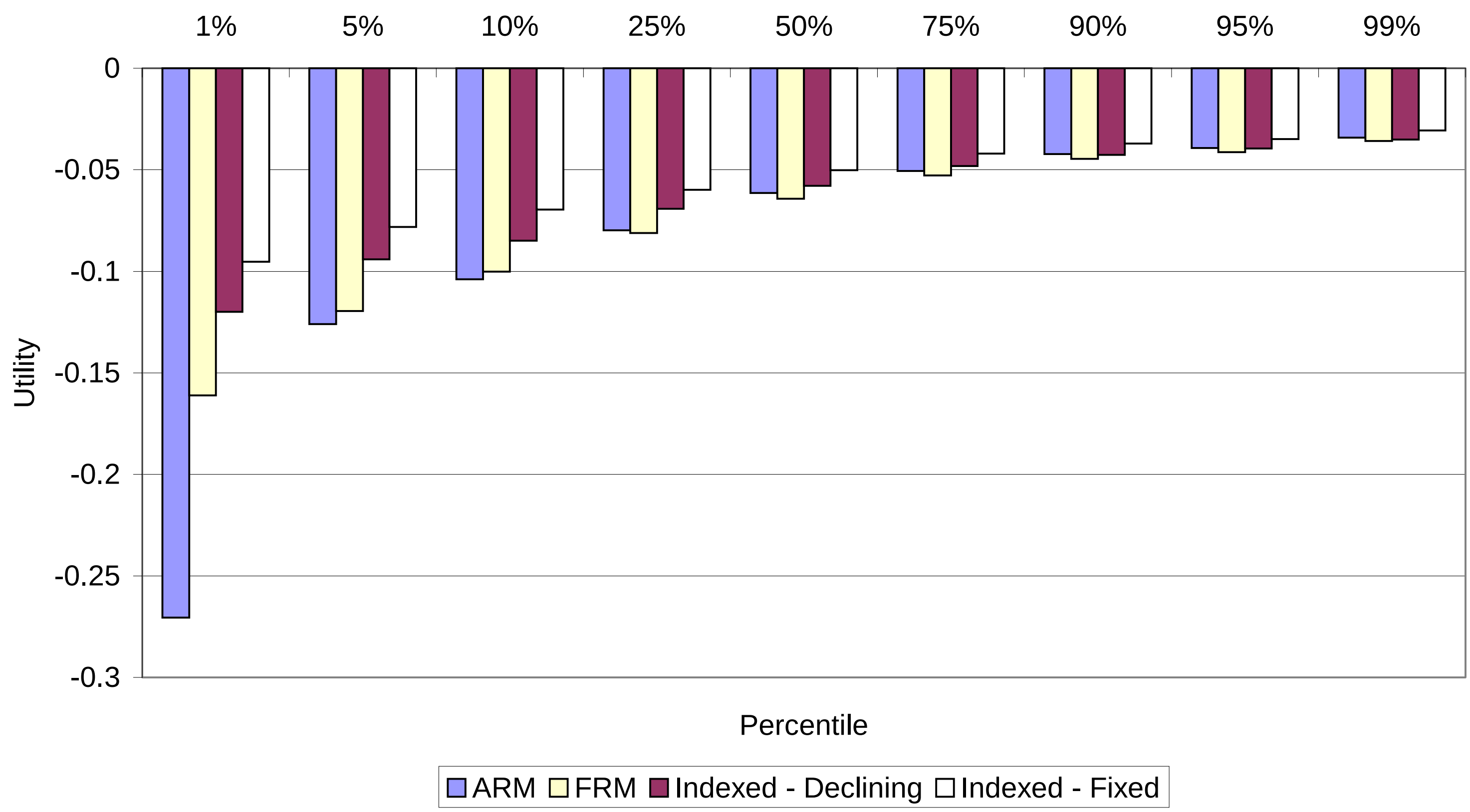


Figure 8: Utility distribution with nominal ARM and FRM and inflation-indexed FRM contracts. This figure shows various percentiles of the distribution of realized utility when we simulate the model for 1,000 households. The parameters of the model are given in Tables 1 and 2, with the size of the house that needs to be financed equal to $150,000. The figure illustrates utility for an ARM and a nominal FRM with refinancing cost of $1,000, an inflation-indexed FRM whose real payments which diminish at the average rate of inflation, and an inflation-indexed FRM with fixed real mortgage payments.