FEDERAL RESERVE BANK of ST. LOUIS

RESEARCH DIVISION

Working Paper Series

The Loan Structure And Housing Tenure Decisions In An Equilibrium Model Of Mortgage Choice

Matthew S. Chambers,
Carlos Garriga
and
Don Schlagenhauf

Working Paper 2008-024B
https://doi.org/10.20955/wp.2008.024

January 2009

FEDERAL RESERVE BANK OF ST. LOUIS
Research Division
P.O. Box 442
St. Louis, MO 63166

The Loan Structure and Housing Tenure Decisions in an Equilibrium Model of Mortgage Choice*

Matthew S. Chambers
Towson University

Carlos Garriga
Federal Reserve Bank of St. Louis

Don Schlagenhauf
Florida State University

This version: December 2008
First version: June, 2005

Abstract

The objective of this paper is to understand how loan structure affects (i) the borrower's selection of a mortgage contract and (ii) the aggregate economy. We develop a quantitative equilibrium theory of mortgage choice where households can choose from a menu of long-term (nominal) mortgage loans. The model accounts for observed patterns in housing consumption, ownership, and portfolio allocations. We find that the loan structure is a quantitatively significant factor in a household's housing finance decision. The model suggests that the mortgage structure preferred by a household is dependent on age and income and that loan products with low initial payments offer an alternative to mortgages with no downpayment. These effects are more important when inflation is low. The presence of inflation reduces the real value of the mortgage payment and the outstanding loan overtime reducing mobility. Changes in the structure of mortgages have implications for risk sharing.

Keywords: Housing finance, first-time buyers, life-cycle
J.E.L.:E2, E6

*We acknowledge the useful comments of Michele Boldrin, Suparna Chakrahorty, John Driscoll, George Fortier, Karsten Jeske, Monika Piazzesi, Martin Schneider, Kjetil Storesletten, Eric Young, participants at the Conference on Housing, Mortgage Finance, and the Macroeconomy held at the Federal Reserve Bank of Atlanta, the System Macroeconomic Meeting held at the Federal Reserve Bank of Dallas, and two anonymous referees. Michele Armesto provided useful assistance. We are grateful to the financial support of the National Science Foundation for Grant SES-0649374. Carlos Garriga also acknowledges support from the Spanish Ministerio de Ciencia y Tecnología through grant SEJ2006-02879. The views expressed herein do not necessarily reflect those of the Federal Reserve Bank of St. Louis nor those of the Federal Reserve System. Corresponding author: Don Schlagenhauf, Department of Economics, Florida State University, 246 Bellamy Building, Tallahassee, FL 32306-2180. E-mail: dschlage@fsu.edu.

1. Introduction

Housing and its financing are important for both households and the overall economy. For households, the importance of housing is evident, as this purchase is typically the largest transaction. The manner in which this purchase is financed is equally important for expenditure patterns and asset accumulation. From a macroeconomic perspective, housing investment (both residential and nonresidential structures) accounts for about half of all gross private investment, and the liabilities from home mortgages are approximately equal to two-thirds of gross domestic product.

Historically, innovations in housing finance have preceded important housing booms that have had ramifications for prices and homeownership rates. In the 1920s, loan-to-value ratios increased and the use of high interest rate second loans became more commonplace. The 1940s saw an expansion of long-term self-amortizing fixed payment mortgages with even higher loan-to-value ratios, as exemplified by 20 percent downpayment loans offered by the Federal Housing Administration. The boom in the early 2000s coincided with the expansion of prime and subprime lending and further increases in loan-to-value ratios and changes in the loan structure that allowed for flexible repayment schedules coupled with initially lower entry costs. The connection between housing finance, housing markets, and the macroeconomy has become apparent given recent turmoil in the subprime mortgage market. The financial turbulence resulting from the housing meltdown has preoccupied policymakers because of the consequences for the aggregate economy.

There is relatively little research that focuses on the implications of the structure of the mortgage contract for either households or the aggregate economy. In a standard textbook model that excludes financial frictions, all mortgage loans are equivalent. However, the evidence suggests that households are subject to constraints that are not fully captured by the canonical model. This partially accounts for the large empirical literature that focuses on the choice between adjustable rate and fixed rate mortgages.[1] The importance of the loan structure has been ignored in the dynamic general equilibrium literature. One reason is that the standard model often employs a one-period mortgage where the downpayment constraint is the only relevant factor that impacts tenure decisions. We argue that it is important to separate the effects of changes in the loan structure from the relaxation of downpayment constraints in an environment with long-term mortgage contracts.

It is important also to acknowledge that the precise mechanisms through which changes in housing finance affect the productive economy and financial markets are not completely understood. The research analyzing the connection between housing finance and the economy is limited partially because of the necessity of first understanding the determinants of mortgage

[1] Most of the literature is empirical and includes Alm and Follain (1984), Dunn and Spatt (1985), Kearl (1979), LeRoy (1996), Stanton and Wallace (1998), and Shilling, Dhillon, and Sirmans (1987). Follain (1990) has written a survey of this literature prior to 1990. An exception is Campbell and Cocco (2003), who solves a numerical model with household mortgage choice over fixed-rate mortgage and adjustable rate-mortgage. They show that fixed rate mortgages should be attractive to risk-averse borrowing constrained households, in particular those with high mortgage debt relative to their income. However, they do not consider different dimensions of fixed-rate mortgage products or the implications for prices and the aggregate economy.

choice. Given the array of mortgage products, the optimal mortgage choice for a household is a complex problem. Households have to take into consideration many dimensions such as the downpayment, maturity of the contract, repayment structure, the ability to refinance, the possibility of being subject to borrowing constraints, and the evolution of economic variables such as the interest rate, inflation, house appreciation, and income growth. For instance, the optimal choice for a buyer moving into the housing market might be different from a homeowner looking to purchase a larger house. Therefore, understanding mortgage decisions requires a framework that explicitly acknowledges the heterogeneity of households across age, income, and wealth dimensions. In addition, these decisions must consider the complexities of the tax code that favors owner-occupied housing. Only in such a framework can we understand mortgage choice across households and its impact on the performance of the overall economy.

The objective of this paper is to understand the effects of mortgage structure, in the form of alternative repayment and amortization schedules, for the household's choice of financing a house and the implications of this choice for the aggregate economy. We want to separate the effects of changes in the structure of the loan from the relaxation of downpayment constraints. Given the complexity of the problem, we restrict our attention to stationary equilibrium in an environment with a restricted set of nominal mortgage contracts that are free from interest rate risk. This restriction does not seem to be major, as more than 90 percent of the households use fixed-rate mortgages. The failure to consider variable interest rate mortgage products could be important for refinancing questions. At the household or individual level, the structure of housing finance affects the patterns of housing consumption, tenure, and mobility. For example, mortgage loans with an increasing repayment structure that track the profile of average labor income growth early in the life-cycle may be attractive to younger, poorer, or borrowing-constrained households. However, for households that are not borrowing constrained and/or have consumption levels that are less correlated with income growth, this loan structure should be less relevant to the participation decision. From a macroeconomic perspective, the available choice of mortgage products can increase the participation in owner-occupied housing markets and residential investment and also improve risk sharing (housing and non-housing goods). Changes in the aggregate level of mortgage debt and the aggregate demand for owner-occupied housing can affect the interest rate and the rental price of tenant-occupied housing.

To understand how the structure of mortgages effects mortgage choice and the aggregate economy, we develop a quantitative equilibrium theory of mortgage choice. In the model households face uninsurable mortality and labor income risks and make decisions with respect to consumption (goods and housing services) and asset allocations (capital and risky housing investment).[2] The model stresses the dual role of housing as a consumption and risky investment good. Investment in housing differs from real capital as a long-term debt (mortgage) contact

[2]It is important to note that in an environment with complete markets, mortgage decisions are irrelevant. Households can always offset any limitation of the mortgage loan (i.e., downpayment requirement) by borrowing or lending in the asset market. Mortgage choice is meaningful in an environment with incomplete markets and with borrowing constraints.

must be used. This debt contract is nominal. Households can choose from a menu of mortgage contracts that differ in downpayment requirement, payment structure, and maturity so that in equilibrium different long-term mortgage loans coexist. House sales are subject to an idiosyncratic capital gains shock that affects the value of the property.[3] Allowing mortgage choice increases the complexity of the computational problem. An environment that allows households to choose over a *large* set of mortgage products is computationally infeasible. As a result, we examine mortgage choice in an environment with a restricted set of mortgage products.

In recent years, there have been a number of papers that have examined housing in the context of a general equilibrium framework with heterogeneous agents. Some of these papers are Berkovec and Fullerton (1992), Chambers, Garriga, and Schlagenhauf (2009), Davis and Heathcoate(2005), J.Díaz and Luengo-Prado (2002), Fernández-Villaverde and Krueger (2002), Gervais (2002), Jeske and Krueger (2005), Li and Yao (2007), Nakajima (2003), Ortalo-Magne and Rady (2006), Sánchez (2007), and Sánchez-Marcos and Ríos-Rull (2006). Much of this literature looks at the tax effects on housing choice or the wealth implications of housing. The paper most related to this one is Chambers, Garriga, and Schlagenhauf (2009) which uses a similar model to account for changes in homeownership in the United States. The emphasis of that paper is on decomposing the observed boom in real estate into demographic changes and the relaxation of the downpayment constraint. We find that roughly two-thirds of the increase in participation can be attributed to the introduction of mortgage loans that relax the loan-to-value (LTV) ratio constraint of young and poor households. The objective of this paper is to emphasize the importance of the loan structure, and not the level of the downpayment, as a determinant of housing finance. To illustrate the differences between both margins, we findings from an environment in which households can choose over a variety of mortgage structures with the findings related to an environmenmt in which the down-payment constraint is relaxed. The primary findings of this paper can be separated into two categories: the effects of loan structure for mortgage choice and the aggregate implications.

We show that the structure of mortgage loans in terms of repayment profiles and amortization schedules is a quantitatively significant factor for a households' mortgage decisions, and has important implications for tenure decisions and the size of the homes consumed. When the downpayment requirement is high, households benefit from the introduction of loan products with a variable nominal repayment structure. An increasing repayment loan structure increases the participation in the owner-occupied market since it reduces the entry costs. In contrast, a decreasing repayment structure shifts the demand away from the fixed-rate mortgage loan as the former contract allows homeowners to maximize the equity in the house. We argue that either the repayment profile of the loan, a decline in the downpayment, or a combination of both results in similar quantitative ways to increase participation in owner-occupied housing. The presence of inflation reduces real payments over the length of the loan. The structure of

[3] There has been a lot of discussion about the high growth rates of house prices. In this paper we do not seek to explain the joint movement of house price and homeownership. The idea behind the introduction of idiosyncratic capital gains is to partially capturing the risk associated to investing in real estate that is realized at sale.

a mortgage has an important impacts on mobility. The presence of inflation reduces the real value of the mortgage payment and the outstanding loan overtime. This makes it easier for a household to upsize their house and lessens the need to downsize their house.

From a more disaggregate perspective, the model provides three important insights . First, the option of using a contract with either low initial mortgage payments or a higher loan-to-value ratio has a positive impact on the participation rate of the lowest income group when compared with the baseline model. This conclusion is independent of the degree of inflation. The presence of inflation reduces the increase in participation for the lowest income group in all cases with the exception of the hybrid case where strong general equilibrium effects are present. Second, the majority of individuals in the two highest income groups prefer loans that maximize the equity in the house such as the traditional FRM or the constant amortization product. This finding is not impacted by inflation. Third, the presence of inflation mitigates some of the negative effects of increasing mortgage payments since its real value declines over the length of the loan.

In economies with incomplete markets and long-term mortgages, changes in the structure of a mortgage has interesting effects on risk sharing. Homeowners can use the repayment structure to smooth income risk. The actions of homeowners has general equilibrium price effects which has beneficial effects for renters. We argue that loan structure can reduce the coefficient of variation of consumption for homeowners. This reduction is especially important when we consider mortgages with an increasing repayment structure and no inflation. The presence of inflation reduces the coefficient of variation of housing services at the expense of goods consumption.

Beyond policy implications, this paper fills a few important gaps in the modeling of the housing market. First, we employ a framework that explicitly models mortgage decisions using contracts that last for several periods. The fact that houses are typically purchased through long-duration mortgages is often ignored in other life-cycle models with housing. Long-duration loans will have an effect on households' ability to accumulate capital assets and smooth income risk. Second, we implement an endogenous rental market where supply and demand is driven completely by household decisions. As a result, we find that our model matches several features of the housing market such as the rate of homeownership, the average house size, and portfolio allocations.

This paper is organized into five sections. In the first section, we describe the properties of different mortgage contracts. In the second section, we describe the model economy and define equilibrium. The third section discusses the estimation of the model to the US economy and analyzes the performance of this model with a standard mortgage contract. In the next section, we examine the implications of mortgage structure resulting from the household's mortgage choice and in the final section we focus on the ramifications of contract structure for the aggregate economy.

2. Mortgage Contracts

2.1. Characteristics of mortgage contracts

A mortgage contract is a loan secured by real property. Mortgage lending is the primary mechanism used in most countries to finance the acquisition of residential property. Since these contracts are a debt contract, they are nominal contracts. These loans are structured as long-term loans that require periodic payments consisting of an interest payment and a principal payment. There are many types of mortgage loans, which can be broadly defined by three characteristics: the payment structure, the amortization schedule, and the term of the mortgage loan. The payment structure defines the amount and the frequency of mortgage payments. The amortization structure refers to the size of the principal payments over the life of the mortgage, and can be increasing, decreasing, or constant. Some contracts allow for no amortization of the principal and full repayment of principal at a given date. Other contracts allow negative amortization usually in the initial periods of the loan. The term or duration usually refers to the maximum length of time given to repay the mortgage loan. The most common durations are 15 and 30 years. In theory, the combination of these three factors allows for a large variety of distinct mortgage products to be constructed. Among this set, only a subset of products exists in the marketplace.

Understanding mortgage loans is essential to understanding owner-occupied housing. In the United States, according to the Residential Finance Survey in 2001, roughly 82.1 percent of the housing units were acquired through mortgage loans while only 11.8 percent were purchased with cash. The remaining acquisitions are financed through by inheritance, gifts, or divorce. A key determinant of housing finance is the set of loan products available to households. Until the 1990s there were two predominant loan types: an adjustable rate mortgage (ARM) and a 30-year fixed rate mortgage (FRM). However, substantial innovation in mortgage markets has expanded the set of loan products, making mortgage choice even more complex. New mortgage contracts have eliminated the necessity of a downpayments and have changed the loan structure. The introduction of these products has increased opportunities for families that otherwise might be unable to purchase a house. According to data from the Mortgage Market Statistical Annual, the market share of nontraditional mortgage contracts has increased since 2000. Nontraditional or alternative mortgage products include interest-only loans, option ARMs, loans that couple extended amortization with balloon payment requirements, and other contracts of alternative lending. For example, in 2004 these products accounted for 12.5 percent of originations. By 2006, the fraction increased to 32.1 percent of originations. With the share of conventional and conforming loans declining over the period 1990 to 2006, it is important to examine the structure of mortgage contacts.

2.2. General structure of mortgage contracts

Despite the differences in the observed types of mortgage contracts, all have the same fundamental elements: a downpayment, an amortization schedule, an interest payment, and outstanding principal. To characterize the various features of mortgage contracts it is useful to introduce some general notation common to all contracts. Let $z \in \mathcal{Z} = \{1, ..., Z\}$ be a specific type of mortgage loan from the set of available contracts that borrowers can use to purchase a house of size h with a unit price p. A mortgage loan usually requires a downpayment to guarantee that there is some equity in the house. We define $\chi(z) \in \mathbb{R}$ to be the fraction of the house value paid up-front by the homeowners. The term $H_0(z) = \chi(z)ph$ represents the initial amount of equity in the house and $D_0(z) = (1 - \chi(z))ph$ represents the value of initial debt owed to the lender. At each period, t, the borrower faces a nominal payment amount that depends on the size of the loan, $D_0(z)$, the term of the mortgage, $N(z)$, the nominal mortgage loan interest rate, $r^m(z)$, and repayment structure associated to each mortgage contract z. We denote the nominal mortgage repayment schedule at time t as being determined by the function $m_t(x, z)$, where x is defined by the set $(p, h, \chi(z), N(z), r^m(z))$. This payment can be decomposed into an amortization term, $A_t(z)$, that depends on the amortization schedule of the mortgage loan and an interest term, $I_t(z)$, that depends on the outstanding debt. That is,

$$m_t(x, z) = A_t(z) + I_t(z), \qquad \forall t, \tag{2.1}$$

where the interest payments are calculated by $I_t(z) = r^m(z)D_t(z)$. The law of motion for the level of housing debt $D_t(z)$ can be written as

$$D_{t+1}(z) = D_t(z) - A_t(z), \qquad \forall t. \tag{2.2}$$

The law of motion for the level of home equity with respect to the loan $H_t(z)$ is

$$H_{t+1}(z) = H_t(z) + A_t(z), \qquad \forall t, \tag{2.3}$$

where $H_0(z) = \chi(z)ph$ denotes the home equity in the initial period.

Notice that this formulation is very general, since it allows 100 percent financing when $\chi(z) = 0$ with an initial loan of $D_0(z) = ph$ and an all-cash purchase with $\chi(z) = 1$ with no initial loan $D_0(z) = 0$. Some contracts even allow closing costs to be rolled into the loan, so the downpayment fraction could be negative, $\chi(z) < 0$. Next, we will discuss the specifics of primary mortgage contract types such as the standard fixed rate mortgage, a constant-amortization loan, a balloon payment loan, combo-loans with a financed downpayment, and graduated mortgage payments loan.

2.3. Fixed Payment or Fixed Rate Mortgage

Fixed payment or fixed rate mortgages (FRM) are considered the "standard" loan product used to finance the purchase of a house. This loan product is characterized by a constant nominal mortgage payment over the term of the mortgage, $m(x, z_{FRM}) = m_1(x, z_{FRM}) = ... = m_N(x, z_{FRM})$. The constant mortgage payment has the property of an increasing amortization schedule of the principal and a decreasing schedule for interest payments. Formally,

$$m(x, z_{FRM}) = A_t(z_{FRM}) + I_t(z_{FRM})$$

and satisfies

$$m(x, z_{FRM}) = \lambda D_0(z_{FRM}),$$

where $\lambda = r^m[1-(1+r^m)^{-N}]^{-1}$. Since the outstanding debt decreases over time, $D_0(z_{FRM}) > ... > D_N(z_{FRM})$, the contract front loads the interest rate payments $I_t(z_{FRM}) = r^m(z_{FRM})D_t(z_{FRM})$, and back loads the capital or principal payments given by

$$A_t(z_{FRM}) = \lambda D_0(z_{FRM}) - r^m(z_{FRM})D_t(z_{FRM}).$$

The level of debt is reduced by the repayment each period -

$$D_{t+1}(z_{FRM}) = (1+r^m)D_t(z_{FRM}) - m(x, z_{FRM}), \qquad \forall t,$$

- and the equity in the house increases each period by the mortgage payment net of interest.

$$H_{t+1}(z_{FRM}) = H_t(z_{FRM}) + \left[m(x, z_{FRM}) - r^m(z_{FRM})D_t(z_{FRM})\right], \qquad \forall t.$$

Because of inflation, even though nominal mortgage payments are constant real payments decline over the length of the loan. The rate of decline depends on the rate of inflation.

2.4. Constant Amortization Mortgage

One of the features of the fixed rate mortgage is that little equity is accrued early in the mortgage due the front loading of interest payments. A contract that does not have this feature is the constant-amortization mortgage. This loan product assumes constant contributions to the amortization schedule, $A_t(z_{CAM}) = A_{t+1}(z_{CAM}) = A(z_{CAM})$, but since the interest repayment schedule depends on the size of outstanding level of debt, $D_t(z_{CAM})$, and the loan term, N, the nominal mortgage payments $m_t(x, z_{CAM})$ are no longer constant. Formally, the constant amortization terms are calculated as

$$A(z_{CAM}) = \frac{D_0(z_{CAM})}{N} = \frac{(1-\chi)ph}{N}.$$

Under this contract, mortgage payments, $m_t(x, z_{CAM})$, decrease over time:

$$m_t(x, z_{CAM}) = \frac{D_0(z_{CAM})}{N} + r^m(z_{CAM})D_t(z_{CAM}).$$

The law of motion for the outstanding level of debt and home equity are represented by

$$D_{t+1}(z_{CAM}) = D_t(z_{CAM}) - \frac{D_0(z_{CAM})}{N}, \qquad \forall t,$$

and

$$H_{t+1}(z_{CAM}) = H_t(z_{CAM}) + \frac{D_0(z_{CAM})}{N}, \qquad \forall t.$$

2.5. Balloon and Interest-Only Mortgages

At the other end of the spectrum we have mortgage contracts with very little or no amortization along the term of the mortgage. One example is the balloon loan where all the principal borrowed is paid in full the last period, N. This product is popular in times where mortgage rates are high and home buyers anticipate lower future mortgage rates. In addition, homeowners who expect to stay in their home for a short duration may find this attractive because the lack of principal payments reduces the total mortgage payments. The amortization schedule can be written as

$$A_t(z_{BAL}) = \begin{cases} 0, & \forall t < N, \\ (1-\chi)ph, & t = N. \end{cases}$$

All the mortgage payments, except the last one, reflect interest rate payments, $I_t\left(z_{BAL}\right) = r^m(z_{BAL})D_0(z_{BAL})$. The mortgage payment for this contract is

$$m_t(x, z_{BAL}) = \begin{cases} I_t(z_{BAL}), & \forall t < N, \\ (1+r^m)D_0(z_{BAL}), & t = N, \end{cases}$$

where $D_0(z_{BAL}) = (1-\chi)ph$. The evolution of the outstanding level of debt can be written as

$$D_{t+1}(z_{BAL}) = \begin{cases} D_t(z_{BAL}), & \forall t < N, \\ 0, & t = N. \end{cases}$$

The other example is the interest-only loan, (BALI). With this mortgage contract the homeowner never accrues more equity in the house than the initial downpayment. In this case, $A_t(z_{BALI}) = 0$ and $m_t(x, z_{BALI}) = I_t(z_{BALI}) = r^m D_0(z_{BALI})$ for all t. With this mortgage the homeowner is effectively renting the property from the lender and the interest payments are the effective rental cost.

Since no additional equity is accrued, nominal mortgage payments are the lowest with this type of mortgage product. The homeowner is fully leveraged with the bank and maximizes the return from housing investment when capital gains are realized. In the presence of mortgage interest deductions, this contract becomes very attractive as the government subsidizes the effective rental cost.

2.6. Graduate Mortgage Payments

In an environment with high housing prices, another product that may be of interest to first-time buyers is the graduated payment-mortgage (GPM), where nominal mortgage payments grow over time. This product could be attractive to first-time buyers as mortgage payments are initially lower than payments associated with a fixed-rate contract. In an environment of increasing income profiles early in the life profile, the GPM contract allows households to keep housing expenses a relatively stable fraction of income. Of course, this product increases the lender's risk exposure because the borrower builds equity in the home at a slower rate than the standard contract, which may explain the lack of popularity of this product.[4] The repayment schedule depends on the growth rate of these payments. We consider two different cases that differ on the growth rate of mortgage payments.

1. **Geometric Growth:** In this type of contract, mortgage payments evolve according to a constant geometric growth rate given by

   $$m_{t+1}(x, z_{GPMG}) = (1 + g)m_t(x, z_{GPMG}),$$

   where $g > 0$. Consequently, the amortization term and interest payments are also growing. Formally,

   $$m_t(x, z_{GPMG}) = A_t(z_{GPMG}) + I_t(z_{GPMG}),$$

   with the initial mortgage payments being

   $$m_0(x, z_{GPMG}) = \lambda_g D_0(z_{GPMG}),$$

   where $\lambda_g = (r^m - g)[1 - (1 + r^m)^{-N}]^{-1}$. The law of motion for the level of debt satisfies

   $$D_{t+1}(z_{GPMG}) = (1 + r^m(z_{GPMG})D_t(z_{GPMG}) - (1 + g)^t m_0(x, z_{GPMG}),$$

   and the amortization term is $A_t(z_{GPMG}) = \lambda_g D_0(z_{GPMG}) - r^m D_t(z_{GPMG})$.

2. **Arithmetic Growth:** In this case, the mortgage payment grows at a constant nominal amount, $\triangle = m_1(x, z_{GPMA}) - m_0(x, z_{GPMA})$. The law of motion for the repayment schedule is

   $$m_{t+1}(x, z_{GPMA}) = m_0(x, z_{GPMA}) + t \cdot \triangle)$$

   The initial payment is calculated as usual and is given by

   $$m_0(x, z_{GPMA}) = \frac{[D_0(z_{GMPA}) + \frac{\triangle N}{r^m}]r^m}{[1 - (1 + r^m)^{-N}]} - \triangle(\frac{1}{r^m} + N).$$

   The law of motion for the outstanding debt is

   $$D_{t+1}(z_{GPMA}) = (1 + r^m)D_t(z_{GMPA}) - (m_0(x, z_{GPMA}) + t \times \triangle).$$

   In this case the amortization term is $A_t = (m_0(x) + t \times \triangle) - r^m D_t$.

[4] In 1974 Congress authorized an experimental FHA insurance program for GPMs. In this program, negative amoritization was permitted, but required higher downpayments so that the outstanding principal balance would never be greater during the life of the mortgage than would be permitted for a standard mortgage insured by FHA. Activity under this program and successor programs has been limited.

2.7. Combo or Piggyback Loan

In the late 1990s the combo or piggyback loan became a popular loan product for those who wanted to avoid large downpayment requirements and personal mortgage insurance (PMI).[5] This loan product amounts to the use two different loans. The primary loan covers a fraction of the total purchase, $D_1(z_{COM}) = (1-\chi)ph$, with a payment schedule, $m_t^1(x, z_{COM})$, and a maturity, N_1. The second loan partially or fully covers the downpayment amount, $D_2(z_{COM}) = \varkappa\chi ph$, where $\varkappa \in (0, 1]$ and represents the fraction of downpayment financed by the second loan. The second loan includes an interest premium, $r_2^m = r_1^m + \zeta$ (where $\zeta > 0$), a nominal mortgage payment, $m_t^2(x, z_{COM})$, and a maturity, $N_2 \leq N_1$. In this case

$$m_t(x, z_{COM}) = \begin{cases} m^1(x, z_{COM}) + m^2(x, z_{COM}), & \text{when } N_2 \leq t \leq N_1 \\ m^1(x, z_{COM}) & \text{when } t < N_2 \end{cases}$$

and the laws of motion for both loans and home equity are computed as in the mortgage with constant repayment. There are different type of combo loans offered in the industry. For example, a "80-15-5" implies a primary loan for 80 percent of the value, a secondary loan for 15 percent, and a 5 percent downpayment. Another special case is the so-called "no downpayment" or a "80-20-0" that corresponds to the traditional LTV rate of 80 percent using a second loan for the 20 percent downpayment.

3. Equilibrium Model of Mortgage Choice

The model economy comprises of households, a representative firm, a financial intermediary, and a government sector. In this section, we discuss each of these elements in detail and define the market-clearing conditions. The formal definition of the recursive equilibrium for this model appears in an appendix.

3.1. Households

The household sector is populated by overlapping generations of *ex ante* identical households that face mortality risk and uninsurable labor earning uncertainty. Household age is denoted by j, where each household lives a maximum of J periods. The survival probability conditional of being alive at age j is given by $\psi_{j+1} \in [0, 1]$, with $\psi_1 = 1$ and $\psi_{J+1} = 0$. Preferences are defined over consumption goods, c, and housing services, d. Bundles of goods are ranked according to an index function, $u : \mathbb{R}_+^2 \to \mathbb{R}$. The function $u(c, d)$ satisfies $u_i > 0$ and $u_{ii} < 0$ with respect to each good, $i = c, d$. The utility function satisfies the standard Inada conditions. Household preferences are given by the expected value of a discounted $\beta > 0$ sum of momentary utility functions, $E\sum_{j=1}^{J}\psi_{j+1}\beta^{j-1}u(c_j, d_j)$.

[5] Government-sponsored mortgage agencies initiated the use of this product in the late 1990s and this product became popular in private mortgage markets between 2001 and 2002.

Besides consumption (goods and housing service) decisions, households make portfolio decisions to smooth out income uncertainty. We consider two distinct assets: a riskless financial asset denoted by $a' \in \mathcal{A}$ with a net (real) return r and a risky housing durable good denoted by $h' \in \mathcal{H}$ with a market price p (where the prime is used to denote future variables). In addition to being an investment good, housing provides services according to the linear technology function $d = g(h') = h'$, which is bounded by the size of the investment, $d \leq h'$. Housing investment is financed through long-term nominal mortgage contracts and is subject to transaction costs.

Household real income is stochastic during working years, $j < j^*$, and depends on a number of factors. Basic wage income is denoted by w. In addition, a household's earnings depend on age. This factor is denoted as υ_j and introduces a life-cycle pattern to earnings. The remaining factor is the idiosyncratic, stochastic factor, $\epsilon \in \mathcal{E}$, which is drawn from a probability space and evolves according to the transition law $\Pi_{\epsilon,\epsilon'}$. During the retirement years, $j \geq j^*$, a household receives a real retirement benefit from the government equal to θ. In addition to earnings on labor and financial wealth defined as $(1+r)a$, a household with a positive housing investment can earn rental income by supplying housing services to the rental market, $R(h'-d)$, where R denotes the rental price. To receive rental income, households have to pay a fixed cost $\varpi > 0$ to enter this market.

Households are subject to a progressive income tax represented by a function $T(ay)$, where ay denotes households' adjusted gross real income, ay.[6] The importance of including a progressive income code is to understand and account for the interaction between mortgage choice and the tax code. Clearly, changes in the tax code and limits on deductions are likely to impact the choice of mortgage. Adjusted income is defined as

$$ay(a,h',d,\epsilon,j,\upsilon_j;q) = \begin{cases} w\epsilon\upsilon_j + ra + R(h'-d) - \Phi, & if \quad j < j^*, \\ \theta + ra + R(h'-d) - \Phi, & if \quad j \geq j^*, \end{cases} \tag{3.1}$$

where $q = \{p, R, r, r^m\}$ represents a price vector and Φ represents deductions to gross real income. Notice that the tax system treats owner-occupied and rental-occupied housing asymmetrically, as rental housing services are taxed while the imputed service flow from owner-occupied housing services are not. The deduction of (real) mortgage payments for owner-occupied housing introduces another asymmetry. After tax income (excluding rental income) is defined as

$$y(a,h',d,\epsilon,j,\upsilon_j;q) = \begin{cases} (1-\tau_p)w\epsilon\upsilon_j + (1+r)a + tr - T(ay), & if \quad j < j^*, \\ \theta + (1+r)a + tr - T(ay), & if \quad j \geq j^*, \end{cases} \tag{3.2}$$

where τ_p represents the social security contributions used to finance the social security system. In the presence of mortality risk and missing annuity markets, we assume borrowing constraints $a' \geq 0$ to prevent households from dying with negative wealth. The proceeds from households that die and have a positive housing investment and/or asset position are redistributed to the

[6] We assume standard properties of a progressive tax function such as differentiability $T'(ay) > 0$ and $T''(ay) < 0$, where $T(ay)/ay > 0$ represents the average income tax.

living households as a lump-sum transfer, tr. We also assume that households are born with some initial wealth.[7]

As we have previously mentioned, housing investment requires long-term financing through nominal mortgage contracts. Since we focus on recursive equilibrium we want to summarize all the relevant information on these long-term mortgage contracts with a finite number of state variables. In a stationary environment, the housing stock, h, the type of mortgage contract, z, and remaining length of the mortgage, n, are sufficient to recover all the relevant information such as the nominal mortgage payment, remaining liability in nominal terms, and nominal equity in the house.[8] Since households make decisions in a real environment, the nominal values from the mortgage contract can be expressed in real terms by dividing by $(1+\pi^e)^{N-n}$, where π^e is the expected rate of inflation. The nominal mortgage interest rate, $r^m(z)$, is defined as the real interest rate, r, plus the expected rate of inflation. The Fisher equation implies that the nominal mortgage rate $r^m = r + \pi^e(1+r)$ where π^e represents the rate of anticipated inflation.

Individuals make decisions about consumption goods, housing services, mortgage contract type, and investment in assets and housing. The household's current-period budget constraint depends on asset holdings, the current housing investment, the remaining length of the mortgage, labor income shock, and household age. We can isolate five possible optimization problems that the household solves. The value function for a household is described by the state vector, which depends on the entering asset position, a; the prior period housing position, h; the number of periods remaining on an existing mortgage, n; mortgage contract type, z; the value of the current-period idiosyncratic shock, ϵ; and age, j. We will always characterize the value function, $v(\Lambda)$, by the order of state variables, $\Lambda = (a, h, z, n, \epsilon, j)$. We can think of the household as being in one of five situations with respect to yesterday's and today's housing investment position.

1. **Renter yesterday and renter today:** Consider a household that does not own a house at the start of the period, $h = n = z = 0$, where $\Lambda = (a, 0, 0, 0, \epsilon, j)$, and decides to continue renting housing services in the current period, $h' = n' = z' = 0$, where $\Lambda' = (a', 0, 0, 0, \epsilon', j+1)$. The decision problem in recursive form can be expressed as

$$v(\Lambda) = \max_{(c,d,a')\in\mathbb{R}_+} \left\{ u(c,d) + \beta\psi_{j+1} \sum_{\epsilon'\in\mathcal{E}} \pi(\epsilon,\epsilon') v(\Lambda') \right\} \tag{3.3}$$
$$s.t. \quad c + a' + Rd = y(a, h', d, \epsilon, v_j, j; q),$$

where Rd denote's the cost of housing services (dwelling) purchased in the rental market. There is no restriction on the size of housing services rented.[9] The restriction on the choice

[7] The purpose of this assumption is to account for the fact that some of the youngest households who purchase housing have some wealth. Failure to allow for the initial asset position creates a bias against the purchase of homes in the earliest age cohorts.

[8] It should be pointed out that h, z, and n are sufficient information to identify information about a contract even when mortgage loans have different maturities, $N(z)$, and interest rates, $r^m(z)$, over the length of the loan.

[9] Other housing papers impose some limits in the size of rental-occupied housing. In this paper, renters can consume any amount of housing services.

set indicates that asset markets are incomplete since short-selling is precluded and only a noncontingent claim on capital is traded.

2. **Renter yesterday and homeowner today:** In this situation, we consider a household that rented the previous period, so $h = 0$ and $\Lambda = (a, 0, 0, 0, \epsilon, j)$, and chooses to purchase a house in the current period, $h^{'} > 0$, where $\Lambda' = (a', h', N(z') - 1, z', \epsilon', j + 1)$. The housing investment requires a choice of mortgage, $z' \in \mathcal{Z}$, to finance an initial expenditure of $(\phi_b + \chi(z'))ph'$, where ϕ_b represents a transaction cost parameter and $\chi(z')$ denotes the downpayment fraction associated with mortgage z'.[10] The period nominal **(and real)** mortgage payment is $m(x, z')$, where $x = (p, h', \chi(z'), N(z'), r^m(z'))$. In this model housing is a consumption and investment good where housing services can be transacted in the market. To participate in the rental market each period as a landlord, households have to pay a fixed operating cost, $\varpi > 0$.[11] For these households, housing consumption satisfies $d < h'$ and they receive rental income, $R(h' - d)$.[12] Otherwise, the optimal housing consumption is entirely determined by the housing stock, $d = h'$. In order to incorporate this decision into the choice problem, we introduce an indicator variable, I_r, that takes on the value of unity when the household chooses to be a landlord and zero otherwise. Formally:

$$v(\Lambda) = \max_{\substack{(c,d,a',h') \in \mathbb{R}_+ \\ z' \in \mathcal{Z},\ I_r \in \{0,1\}}} \left\{ u(c, d) + \beta \psi_{j+1} \sum_{\epsilon' \in \mathcal{E}} \pi(\epsilon, \epsilon') v(\Lambda') \right\}, \tag{3.4}$$

$$s.t. \quad c + a' + (\phi_b + \chi(z'))ph' + m(x, z') + g(h', d) = y(a, h', d, \epsilon, \upsilon_j, j; q) + I_r \left[R(h' - d) - \varpi \right],$$
$$d \leq h'.$$

Owning property requires a maintenance expense each period. The total maintenance cost depends on the choice to supply rental property. If homeowners choose not to supply housing services to the rental market (i.e., $I_r = 0$), then $d = h'$ and the maintenance expense is given by $g(h', d) = \delta_o ph'$, where δ_o represents the depreciation rate of owner-occupied housing. Alternatively, a household can choose to supply housing services to the rental market (i.e., $I_r = 1$). In this case, maintenance expense depends on the amount of housing supplied to the rental market and their own consumption and is defined as

[10] For computational reasons χ is not a choice variable in the model. The endogenous choice of downpayment would require keeping track of an additional state for the downpayment choice since this decision is dynamic. A higher downpayment today reduces both current and future mortgage payments.

[11] The decision to supply rental property is entwined with the decision to invest in housing. The separation of housing consumption services and housing investment allows the rental market to be formalized while keeping the state space relatively tractable. Introducing two different housing stocks such as owner-occupied and rental-occupied would require an additional portfolio choice, making the problem computationally infeasible.

As a result, all the landlords are homeowners but the not the other way around. Nevertheless, the American Housing Survey reports that the fraction of individuals that report to receive rental income and rent the house they occupy is practically zero.

[12] This formulation implies that a household that leases property uses a mortgage with a downpayment of χ percent of the value of the property. Although this may seem to be an unrealistic assumption, the POMS Survey reports that 81.1 percent of rental property owners used some sort of mortgage financing in financing the acquisition of rental property.

$g(h', d) = \delta_o pd + \delta_r p(h' - d)$, where δ_r represents the depreciation rate of rental housing. The presence of moral hazard associated with renting property implies that there is a spread in depreciation rates ($\triangle\delta = \delta_r - \delta_o > 0$) that reduces the implicit cost of owner-occupied consumption. The choice of rental supply is complex because landlords not only take into account the maintenance expense, but the tax provisions with respect to rental-income. For a more detailed analysis of the tax treatment of homeowners and landlords, see Chambers, Garriga, and Schlagenhauf (2007).

3. **Homeowner yesterday and renter today:** In this situation we consider a household that is selling the property $h > 0$, where $\Lambda = (a, h, n, z, \epsilon, j)$, to become a renter in the current period $h' = 0$, where $\Lambda' = (a'_\xi, 0, 0, 0, \epsilon', j + 1)$ [13] The decision to sell property reveals why housing is a risky investment. At the moment of sale, the household is subject to an idiosyncratic capital gain or amenity shock, $\xi \in \Xi$. This shocks impacts the selling value of the property by changing the size of the housing investment.[14] This shock is not revealed until the house is sold. We assume this shock is i.i.d. and discrete. The unconditional probability of the shock is π_ξ. The optimization problem for this situation is

$$v(\Lambda) = \max_{(c_\xi, d_\xi, a'_\xi) \in \mathbb{R}_+} \left\{ \sum_{\xi \in \Xi} \pi_\xi [u(c_\xi, d_\xi) + \beta\psi_{j+1} \sum_{\epsilon' \in \mathcal{E}} \pi(\epsilon, \epsilon') v(\Lambda'_\xi)] \right\}, \tag{3.5}$$
$$s.t. \quad c_\xi + a'_\xi + Rd_\xi = y(a, h', d, \epsilon, \upsilon_j, j; q) + \Pi_\xi,$$

where $\Pi_\xi = (1 - \phi_s)p\xi h - (D(n, z)/(1 + \pi^e)^{N(z)-n})$ represents the net profit from selling the house, which depends on the real income received from selling the property, $p\xi h$, selling transactions costs, ϕ_s, and remaining real value of outstanding principle, if any, $D(n, z)/(1+\pi^e)^{N(z)-n}$.[15] Notice that the consumption of goods, housing services, and savings are conditioned on the idiosyncratic shock since net income depends on the realization of ξ.

4. **Homeowner yesterday and homeowner today:** The last case focuses on a household that enters the period with a housing investment, $h > 0$, with a state $\Lambda = (a, h, n, z, \epsilon, j)$, and decides to continue to have a housing investment position. A critical issue is whether the household decides to change their housing investment position.

[13] In the last period, all households must sell h, rent housing services, and consume all their assets, a, as a bequest motive is not in the model. In the last period, $h' = a' = 0$.

[14] The idiosyncratic capital gain shock introduces a form of risk into the housing investment decision without having to introduce an aggregate shock. Adding aggregate uncertainty is not compuationally feasible in this model at this time. This shock can be thought of as what happens to a property if the surrounding neighborhood deteriorates or improves. This change would be reflected in the house value at the time of sale. An additional advantage of the formulation is that it eliminates the necessity of matching buyers and sellers, as any buyer can always purchase a brand new home with independence of the shock received by the seller.

[15] Since our analysis is conducted at the steady state, other than the differences between buying and selling transaction costs, there are no differences in the purchase and selling prices of housing.

(a) Cash-out refinance option: The household can decide to maintain their housing investment position, in which case $h = h'$. In addition, the household has the option to continue with their existing mortgage, if one exists, or refinance. The refinancing decision can be expressed as

$$v(a, h, n, z, \epsilon, j) = \max[v_1(a, h, n, z, \epsilon, j), v_2(a, h, n, z, \epsilon, j)]. \tag{3.6}$$

If the household continues with their mortgage, then $z = z'$ and $\Lambda' = (a', h', n - 1, z, \epsilon', j+1)$. This optimization problem can be written as

$$v_1(\Lambda) = \max_{\substack{(c,d,a')\in\mathbb{R}_+ \\ I_r\in\{0,1\}}} \left\{ u(c,d) + \beta\psi_{j+1} \sum_{\epsilon'\in\mathcal{E}} \pi(\epsilon,\epsilon')v(\Lambda') \right\}$$

$$\begin{aligned} s.t. \quad c + a' + m(x, z')/(1+\pi^e)^{N(z)-n} + x(h', s) &= y(a, h', s, \epsilon, \upsilon_j, j; q) + I_r \left[R(g(h') - s) - \varpi\right] \\ d &\leq h', \end{aligned}$$

where $v_1(a, h, n, z, \epsilon, j)$ denotes the optimal value associated with the continuation of the existing mortgage contract and $n' = \max\{n-1, 0\}$. If $n' > 0$, a mortgage payment is required. The decision on the amount of housing services to consume - and thus maintenance expenses- depends on the choice of paying a fixed cost ϖ to become a landlord. When the homeowner refinances we assume that the equity position does not change since we assume that is not subject to the capital gain shock.

A household can choose to refinance their mortgage and possibly change their equity position. In this situation, $z \neq z'$, $\Lambda' = (a', h', N(z')-1, z', \epsilon', j+1)$, and the household problem becomes

$$v_2(\Lambda) = \max_{\substack{(c,d,a',h')\in\mathbb{R}_+ \\ z'\in\mathcal{Z},\ I_r\in\{0,1\}}} \left\{ u(c,d) + \beta\psi_{j+1} \sum_{\epsilon'\in\mathcal{E}} \pi(\epsilon,\epsilon')v(\Lambda') \right\},$$

$$\begin{aligned} s.t. \quad c + a' + \chi(z')ph' + m(x, z') + x(h', s) &= y(a, h', s, \epsilon, \upsilon_j, j; q) + I_r \left[R(h' - s) - \varpi\right] \\ &\quad - \varkappa + [ph - D(n, z)/(1+\pi^e)^{N(z)-n}], \\ d &\leq h', \end{aligned}$$

where $v_2(a, h, n, z, \epsilon, j)$ is the value function associated with the z' that generates the greatest value function from the set of mortgage contracts,$\mathcal{Z}$, and $\varkappa$ allows for a fixed cost associated with refinancing. This individual is taking a new loan for the amount $\chi(z')ph'$ and extract equity amounting to $[ph - D(n, z)/(1+\pi^e)^{N(z)-n}]$. The net cost of these two different terms determines whether the homeowners are paying off their house faster, using some of the equity in the house to increase consumption, or just changing the mortgage contract to have a longer maturity.

Clearly, if $v_2(a,h,n,z,\epsilon,j) > v_1(a,h,n,z,\epsilon,j)$ then refinancing occurs. In our formulation, refinancing is not subject to capital gains shocks.[16] This mechanism provides an additional margin to smooth temporary negative income shocks.

(b) Homeowner changes housing size: If the household decides to either up-size or down-size their housing investment position, $(h \neq h', h > 0, h' > 0)$ and $\Lambda'_\xi = (a'_\xi, h'_\xi, N-1, z', \epsilon', j+1)$, then household problem becomes

$$v(\Lambda) = \max_{\substack{(c_\xi, d_\xi, a'_\xi, h'_\xi)\in\mathbb{R}_+ \\ z'\in\mathcal{Z},\ I_r\in\{0,1\}}} \left\{ \sum_{\xi\in\Xi} \pi_\xi [u(c_\xi, d_\xi) + \beta\psi_{j+1} \sum_{\epsilon'\in\mathcal{E}} \pi(\epsilon,\epsilon') v(\Lambda'_\xi)] \right\} \tag{3.7}$$

$$\begin{aligned} s.t. \quad & c_\xi + a'_\xi + (\phi_b + \chi(z'))ph'_\xi + m(x,z') + g(h',d) \\ &= y(a,h',d,\epsilon,\upsilon_j,j;q) + tr + I_s\left[R(h'_\xi - s_\xi)\right] + \Pi_\xi, \\ & d_\xi \leq h'_\xi. \end{aligned}$$

This constraint accounts for the additional (real) income from selling their home Π_ξ, the cost of buying a new home with mortgage product z', as well as the capital gain shock associated with the sale of the home. Just as in the third case, optimal choices depends on the realization of the idiosyncratic shock ξ. In this case, savings and household investment depend on this shock.

3.2. The Financial Intermediary

The financial intermediary is a zero-profit business. The firm receives the deposits of the households, a', and uses these funds to make loans to firms and households. Firms take out loans of capital to produce goods and households require long-term mortgages to finance the investment in housing. They receive mortgage payments from homeowners, principal payments from individuals who sell their home with remaining principle on their mortgage, and principle payments from individuals who unexpectedly die. The financial intermediary's balance sheet determines the equilibrium condition in the asset market. This is discussed in more detail in the Appendix.

3.3. The Production Sector

The production sector is relatively standard. Firms produce according to a constant returns-to-scale technology, $Y = f(K,L)$, where K and L are aggregate inputs of capital and labor, respectively. We assume that capital depreciates at the rate $\delta > 0$ each period. Firms' output can be used for consumption, capital investment, or housing purposes.

[16] This assumption prevents households from extracting equity associated with capital gains. Since in the model we do not have aggregate shocks, the transitory shocks should not have an effect on the homeowner's ability to take on more debt.

3.4. Government

In this economy, the government engages in a number of activities: financing some exogenous government expenditure, providing retirement benefits through a social security program, and redistributing the wealth of those individuals who die unexpectedly. We assume that the financing of government expenditures and social security are managed under different budgets.

In the general budget constraint, revenues are generated from the taxation of adjusted income. We have previously defined $T(ay)$ as the tax obligations given adjusted income. We define $t(\Lambda)$ to be the tax obligations of a representative household based on their state space. In this situation, government revenue is given by

$$G = T = \int \mu_j t(\Lambda)\Phi(d\Lambda), \tag{3.8}$$

and thus government expenditure is determined by the amount of revenue collected from the income taxation. The term $\Phi(\Lambda)$ represents the measure of individuals in a given point in the state space, $\Lambda \equiv (a, h, n, z, \epsilon, j)$, where $\Phi(d\Lambda) \equiv \Phi(da \times dh \times dn \times dz \times d\epsilon \times dj)$.

The government provides social security benefits to retired households. The benefit, θ, is based on some fraction, $\overline{\theta}$, of the average income of workers. These payments are financed by taxing the wage income of employed households at the rate τ_p. Since this policy is self-financing, the tax rate depends on the replacement ratio parameter $\overline{\theta}$. The social security benefit is defined as

$$\theta \equiv \overline{\theta} \sum_{j=1}^{j^*-1} \sum_i \mu_j (wv_j \epsilon_i) / \sum_{j=1}^{j^*-1} \mu_j,$$

where μ_j is the size of the age j cohorts. The social security budget constraint is

$$\tau_p \sum_{j=1}^{j^*-1} \sum_i (\mu_j w v_j \epsilon) = \theta \sum_{j^*}^{J} \mu_j. \tag{3.9}$$

The final role of the government is to collect the physical and housing assets of those individual who unexpectedly die. Both of these assets are sold and any outstanding debt on housing is paid off. The remaining value of these assets is distributed to the surviving households as a lump-sum payment, tr. This transfer can be defined as

$$tr = Tr/(1 - \mu_1),$$

where Tr is the aggregate (net) value of assets accumulated over the state space from unexpected death and is defined as[17]

$$Tr = \int \mu_j(1-\psi_j)a(\Lambda)\Phi(d\Lambda) + \sum_{\xi\in\Xi}\pi_\xi \int \mu_j(1-\psi_j)[(1-\phi_s)p\xi h(\Lambda) - (D(\Lambda)/(1+\pi^e)^{N(z)-n})]\Phi(d\Lambda). \tag{3.10}$$

3.5. Market Clearing Conditions

This economy has four markets: the asset market, labor market, the rental of housing services market, and the goods market. All markets are assumed to be competitive. The market clearing condition in the goods market is given by

$$C + K' - (1-\delta)K + I_H + G + \Upsilon = F(K, L), \tag{3.11}$$

where C, K, G, I_H, and Υ represent aggregate consumption, aggregate investment in real capital, aggregate government spending, aggregate housing investment, and various transaction costs, respectively. Each of these aggregates are define more formally in the appendix, where the recursive stationary equilibrium is defined. In the labor market, the equilibrium wage is determined by the marginal product of labor, $w = F_2(K, L)$, where labor is supplied inelastically in the model and determined by $L = \sum_{j=1}^{j^*-1}\sum_\epsilon \mu_j v_j \epsilon$.

The asset market clearing condition is complicated by the presence of mortgages, unexpected death, and idiosyncratic capital gain shocks. In order to simplify the notation, let $I_s(\Lambda)$ be an indicator function that is equal to one when a housing investment position is sold and zero otherwise. This function will help identify when idiosyncratic capital gain shocks are present. The equilibrium condition in the asset market is

$$\begin{aligned} K' = &\int_{I_s(\Lambda)=0} \mu_j a'(\Lambda)\Phi(d\Lambda) + \int_{I_s(\Lambda)=1} \sum_{\xi\in\Xi} \pi_\xi \mu_j a'_\xi(\Lambda)\Phi(d\Lambda) \\ &- \int_{I_s(\Lambda)=0} \mu_j(1-\chi)ph'(\Lambda)\Phi(d\Lambda) - \int_{I_s(\Lambda)=1} \sum_{\xi\in\Xi} \pi_\xi \mu_j (1-\chi)ph'_\xi(\Lambda)\Phi(d\Lambda) \qquad (3.12) \\ &+ \int_{I_s(\Lambda)=0} \mu_j(m(x,z)/(1+\pi^e)^{N(z)-n})\Phi(d\Lambda) + \int_{I_s(\Lambda)=1} \sum_{\xi\in\Xi} \pi_\xi \mu_j (m(x,z)/(1+\pi^e)^{N(z)-n}) \\ &\qquad (3.13) \\ &- \int_{I_s(\Lambda)=0} \mu_j(D(\Lambda)/(1+\pi^e)^{N(z)-n})\Phi(d\Lambda) - \int_{I_s(\Lambda)=1} \mu_j(1-\psi_j)(D(\Lambda)/(1+\pi^e)^{N(z)-n})\Phi(d\Lambda) \end{aligned}$$

The left-hand side of this equation indicates the total amount of capital available to loan to firms, while the right- hand side measures the sources of this capital. The first line on the right-hand side of the equation captures the savings deposited by households to the financial

[17] The new generation receives a lump sum transfer as we endow these individuals with capital assets observed in the data. The aggregate mass of households of age 1 is μ_1 and the total population is normalized to unity.

intermediary. The first of these terms measures household deposits if the housing position is not sold while the second term on this line allows the deposit decision to be impacted by the idiosyncratic capital gain shock when the housing position is sold. From the total of household deposits, new mortgage loans must be subtracted. The second line on the right-hand side measures new mortgages and allows for differences created by idiosyncratic capital gains shocks. The third line measures an additional source of loanable funds as mortgage payments received by the financial intermediary. This includes payments received by first-time buyers and existing homeowners who continue to make payments on their mortgage, as well as those homeowners who sell property and have a new mortgage payment, which is affected by the idiosyncratic capital gain shock. The last line on the right-hand side of the equation captures the repayment of remaining mortgage principal from households who sell their house as well as the repayment of outstanding debt of households who unexpectedly die with outstanding principal.

In this model, the rental market is endogenous. Individuals who cannot afford to buy a house must purchase or rent housing services. Rental property is supplied by those individuals that have a positive housing investment position and pay the fixed cost $\varpi > 0$ to supply rental property (i.e., $h' - d > 0$). Households who supply housing services receive $R(h' - d)$ gross rental income. The rental price, R, adjusts to equate the aggregate demand for housing services with the aggregate supply of rental services. The rental market equilibrium condition is

$$\int_{I_s(\Lambda)=0} \mu_j [h'(\Lambda) - d(\Lambda)]\Phi(d\Lambda) + \int_{I_s(\Lambda)=1} \sum_{\xi \in \Xi} \pi_\xi \mu_j [h'_\xi(\Lambda) - d_\xi(\Lambda)]\Phi(d\Lambda) = \tag{3.14}$$

$$\int_{I_s(\Lambda)=0} \mu_j d(\Lambda)\Phi(d\Lambda) + \int_{I_s(\Lambda)=1} \sum_{\xi \in \Xi} \pi_\xi [\mu_j d_\xi(\Lambda)\Phi(d\Lambda).$$

The left-hand side of the question measures the supply of housing services while the right-hand side measures the demand for housing services. On both sides of the equation, home sellers are differentiated from non-sellers by recognizing that rental choices for home sellers are contingent on the realization of the capital gain shock, ξ.

4. Parameterization

We parameterize the model to match some key moments of the U.S. economy. This strategy allows us to specify a limited number of parameter values while estimating the remaining parameters as an exercise in exactly identified generalized method of moments. With the parameterized model, we will evaluate the impact of different mortgage contracts across various dimensions.

4.1. Demographics

Each period in the model is taken to be three years. Individuals enter the labor force at age 20 (model period 1) and potentially live till age 86 (model period 23). Retirement is assumed to be mandatory at age 65 (model period 16). Individuals survive to the next period with probability

$\psi_{j+1.}$ These probabilities are set at survival rates observed in 1994, and the data are from the National Center for Health Statistics, *United States Life Tables*, 1994. The size of the age-specific cohorts, μ_j, need to be specified. Because of our focus on steady-state equilibrium, these shares must be consistent with the stationary population distribution. As a result, these shares are determined from $\mu_j = \psi_j \mu_{j-1}/(1+\rho)$ for $j = 2, 3, ..., J$ and $\sum_{j=1}^{J} \mu_j = 1$, where ρ denotes the population growth rate. Using the resident population as the measure of the population, the annual growth rate is set at 1.2 percent.

4.2. Preferences and Technology

The choice of utility function is based on the empirical evidence that suggests that the h/c ratio increases by age as suggested by Jeske (2005). He points out that standard constant relative risk aversion with a homogenous of degree one aggregator, $U(c, d) = (c^\gamma d^{1-\gamma})^{1-\sigma}/(1-\sigma)$, has the implication that the ratio of housing service to consumption stays constant over the life cycle, even though this preference specification is capable of replicating the housing profiles by age as shown by Li and Yao (2007).[18] To match the hump-shaped profiles of housing (h) and goods consumption (c), and the increasing ratio (h/c), we assume that preferences are represented by the period utility function of the form

$$U(c, d) = \gamma \frac{c^{1-\sigma_1}}{1-\sigma_1} + (1-\gamma) \frac{d^{1-\sigma_2}}{1-\sigma_2}$$

The coefficients, σ_1, and σ_2, determine the curvature of the utility function with respect to consumption and housing services. The relative ratio of σ_1 and σ_2 determines the growth rate of the housing-to-consumption ratio. A larger curvature in consumption relative to the curvature in housing services implies that the marginal utility of consumption exhibits relatively faster diminishing returns. When household income increases over the life-cycle (or different idiosyncratic labor income shocks), a larger fraction of resources are allocated to housing services. We set $\sigma_2 = 1$ and $\sigma_2 = 3$ to match the observed average growth rate while the preference parameter γ is estimated.

The choice of technology is relatively standard. We assume that the aggregate production function is Cobb-Douglas, $F(K, L) = K^\alpha L^{1-\alpha}$, with the capital share parameter α set to 0.29. This value is calculated by dividing private fixed assets plus the stock of consumer durables less the stock of residential structures by output plus the service flows from consumer durables less the service flow from housing.[19] Since the firm's output can be used for either consumption, housing investment, or capital good investment, the relative price of housing, p, is equal to one.

[18] We also find that such a momentary utility function generates insufficient movements in the housing position and introduces some counterfactual implications for the rental market.

[19] A data appendix is available that details the calculation of this parameter as well as other parameters used in the paper.

4.3. Endowments

Workers are assumed to have an inelastic labor supply, but the effective quality of their supplied labor depends on two components. One component is age-specific, υ_j, and is designed to capture the "hump" in life cycle earnings. We use data from U.S. Bureau of the Census ("Money, Income of Households, Families, and Persons in the Unites Stated, 1994," *Current Population Reports*, Series P-60) to construct this variable. The other component captures the stochastic component of earnings and is based on Storesletten, Telmer, and Yaron (2004). We discretize this income process into a five-state Markov chain using the methodology presented in Tauchen (1986). The values we report reflect the three-year horizon employed in the model. As a result, the efficiency values associated with each possible productivity value ϵ are

$$\epsilon \in \mathcal{E} = \{4.41, 3.51, 2.88, 2.37, 1.89\}$$

and the transition matrix is

$$\pi = \begin{bmatrix} 0.47 & 0.33 & 0.14 & 0.05 & 0.01 \\ 0.29 & 0.33 & 0.23 & 0.11 & 0.03 \\ 0.12 & 0.23 & 0.29 & 0.24 & 0.12 \\ 0.03 & 0.11 & 0.23 & 0.33 & 0.29 \\ 0.01 & 0.05 & 0.14 & 0.33 & 0.47 \end{bmatrix}.$$

Each household is born with an initial asset position. The purpose of this assumption is to account for the fact that some of the youngest households who purchase housing have some wealth. Failure to allow for this initial asset distribution creates a bias against the purchase of homes in the earliest age cohorts. As a result we use the asset distribution observed in *Panel Study on Income Dynamics* (PSID) to match the initial distribution of wealth for the cohort of age 20 to 23. Each income state is assigned its corresponding level of assets to match the nonhousing wealth- to-earnings ratio.

4.4. Housing

The housing market introduces a number of parameters. The purchase of a house requires a mortgage and downpayment. In this paper we focus on the 30-year fixed rate mortgage as the benchmark mortgage. As a result of the assumption that a period is three years, we set the mortgage length, N, to ten periods. The downpayment requirement, χ, is set to 20 percent, which matches information from the *American Housing Survey*.[20] The mortgage rate, r^m, is a nominal variable and is equal to the real interest rate, r, plus the expected or anticipated inflation rate, π^e. We set the expected inflation rate to 2.4 percent which corresponds to the average inflation rate observed for the period 1995-2004 using the GDP deflator.

[20] The model allows for a fixed cost associated with refinancing. We set $\varkappa$ equal to zero so that refinancing has the best chance to occur in the model.

Buying and selling property is subject to transaction costs. We assume that all these costs are paid by the buyer and set $\phi_s = 0$ and $\phi_b = 0.06$.

Because of the lumpy nature of housing, the specification of the second point in the housing grid has important ramifications. This grid point, $\underline{h}$, determines the minimum house size and has implications for the timing of the purchase of housing investment, wealth portfolio decisions, and the homeownership rate. We determine the value of $\underline{h}$ as part of the estimation problem to avoid any inadvertent effects on the results that would come from choosing this parameter.

As previously explained, housing depreciates at rates that depend on whether the property is owner-occupied or rented. The values for δ_o and δ_r are estimated.

We used data from the 1995 *American Housing Survey* to quantify the i.i.d. capital gains shock. To calculate the probability distribution for this shock, we measure capital gains based on the purchase price of the property and what the property owner believes to be the current market value. This ratio is adjusted by the holding length to express the appreciation in annualized terms. Then we estimate a kernel density and discretize the density in three even partitions. The average annualized price change $\xi \in \{0.934, 0.987, 1.092\}$ and $E(\xi) = 1$. Appropriate adjustments were made for our model where a period corresponds to a three-year period.[21]

4.5. Government and the Income Tax Function

The government has three functions in the model. Income is provided to retired individuals through a social security program. The social security budget constraint involves two parameters: the replacement ratio, $\overline{\theta}$, and the social security tax rate. We set the replacement ratio to be 30 percent and solve for the payroll tax rate consistent with the budget constraint. In this case, the payroll tax is 5.25 percent.

Government spending is financed through income taxation. To get an accurate assessment of housing policy wedges, we want the income tax code to be a good approximation of the actual U.S. tax code. Gouveia and Strauss (1994) estimated a functional form for the U.S. federal income tax code that is theoretically motivated by the equal sacrifice principle. The actual tax paid by a household, $T(ay)$, is based on adjusted gross income and is determined by the functional form

$$T(ay) = \eta_0(ay - (ay^{-\eta_1} + \eta_2)^{\frac{-1}{\eta_1}}),$$

where (η_0, η_1, η_2) are policy parameters. The marginal income tax rate is

$$T'(ay) = \eta_0(1 - (1 + \eta_2 y^{\eta_1})^{-\frac{1}{\eta_1}-1}).$$

This functional form is very flexible and allows for lump-sum ($\eta_1 = -1$), proportional ($\eta_1 \rightarrow 0$), or progressive taxes ($\eta_1 > 0$) as special cases. The parameter η_0 is a scaling factor that

[21] To test the robustness of the results based on data from the *American Housing Survey,* we employed a similar approach using 1995 Tax Roll Data for Duval County in Florida. Jacksonville is the major city in Duval County. These data follows real estate properties as opposed to individuals. We calculated annualized capital gains based on actual sales. We found very similar estimates for the capital gains shock using this data source.

determines the level of the tax brackets and the marginal tax rate but does not impact the curvature of the tax function. The parameter η_2 depends on units of measurement used to measure income and determines the size of income deduction. Gouveia and Strauss estimate the policy parameters and find that $\eta_0 = 0.258$, $\eta_1 = 0.768$, and $\eta_2 = 0.003710$. In the benchmark economy we use the same parameter estimates used by Gouveia and Strauss for η_1 but η_2 is set to 0.3710 to accommodate the model measurement units. The parameter η_0 is determined in the estimation section to pin-down the share of federal revenue in GDP. Following the provisions of the current income tax code, we allow mortgage interest payments and maintenance expenses for rental property to be deducted from income that is taxable. In addition, rental income is taxable, but the imputed rental value of owner-occupied housing is not.[22]

4.6. Estimation

We estimate seven parameters using an exactly identified method of moments approach. The parameters that need to be estimated are the depreciation rate of the capital stock, δ, the depreciation rate for rental units, δ_r, the depreciation rate for ownership units, δ_o, the relative importance of consumption goods to housing services, γ, the discount rate, β, the size of the smallest housing investment position, and the tax function parameter, η_0. We identify these parameter values so that the resulting aggregate statistics in the model economy are equal to seven targets observed in the U.S. economy.

1. **Ratio of wealth to gross domestic product** (K/Y) : This target is the ratio of capital to gross domestic product (GDP), which is about 2.541 (annualized value) for the period 1958-2001; we define the capital stock as private fixed assets plus the stock of consumer durables less the stock of residential structures to be consistent with capital in the model. We measure GDP to be consistent with output in the model. That is, output is measured as reported GDP plus service flows from consumer durables less the service flow from housing.[23]

2. **Ratio of housing stock to fixed capital stock** (H/K) : In this ratio, the housing capital stock is defined as the value of fixed assets in owner and tenant residential property. The housing stock data is from the fixed asset tables of the Bureau of Economic Analysis. We find the ratio of the housing stock to nonhousing capital stock to be 0.43.

3. **Ratio of housing investment to housing stock** (x_H/H) : The ratio of the investment in residential structures to housing capital stock is targeted at 0.04.

4. **Ratio of housing services to consumption of goods** (Rs_c/c) : The targeted ratio of housing consumption to nonhousing consumption is also based on NIPA data where

[22] Since this paper focuses is on the loan structure, we have abstracted from property taxes. In an earlier version of the manuscript we allowed property tax payments and the deduction of this payment in the tax calculation. We found that the introduction of property taxes had no quantitative effect in the results, and thus ignored these taxes in this version for the sake of simplicity.

[23] We estimated service flows using procedures outlines in Cooley and Prescott (1995).

housing services are defined as personal consumption expenditures for housing and non-housing consumption is defined as nondurable and services consumption expenditures net of housing expenditures. The targeted ratio for 1994 is 0.23, but the number does not vary greatly over the period 1990-2000. This value is from Jeske (2005).

5. **Ratio of fixed capital investment to GDP** $(\delta K/Y)$: The fifth target is the ratio of investment in capital goods to output, which is 0.135.

6. **Homeownership rate:** This target is based on data from the *American Housing Survey* for 1994 and is equal to 64.0 percent.

7. **Ratio of government expenditure to output** $(T(ay)/Y)$: The final target using NIPA data is the government expenditure-to-output ratio. We define government expenditure as federal government expenditures. The parameter η_0 is endogenously determined when solving the model to target the 7.4 percent ratio of federal government expenditure-to-GDP observed in 1994.[24]

Table 1 summarizes the parameter estimates and the empirical targets. The moments and the parameter values are presented in annual terms.

Table 1: Method of Moments Estimates (values in annual terms)

Statistic	Parameter	Moment	Model	%Error
1) Ratio of wealth to gross domestic product	$\beta = 0.977$	2.541	2.5418	0.0003
2) Ratio of housing stock to Fixed capital stock	$\delta_o = 0.033$	0.430	0.4241	-0.0138
3) Housing Investment to Housing Stock ratio	$\delta_r = 0.069$	0.040	0.0398	-0.0047
4) Ratio housing services to consumption of goods	$\gamma = 0.954$	0.230	0.2291	-0.0038
5) Ratio fixed capital investment to GDP	$\delta_k = 0.041$	0.135	0.1347	-0.0022
6) Homeownership Rate	$\underline{h} = 1.453$	0.640	0.6397	-0.0005
7) Government expenditure to output ratio	$\eta_0 = 0.205$	0.074	0.0741	0.0008

The implied targets generated by the model solution are within 1 percent error for all the observed targets. The estimation of the structural parameters is not separated from the computation of equilibrium (households optimization problem and market clearing), which includes three additional nonlinear equations (asset market, government budget constraint, and accidental bequest) to include in the distance minimization routine that must be satisfied in conjunction with the moments observed in the data.

4.7. Model Evaluation

The baseline economy is estimated to match certain key features of the U.S. economy in 1994. Since we want to use the model to evaluate mortgage contract choice, it is important to briefly

[24] The Gouveia and Strauss tax function was estimated for the period 1979-1989. As our model is calibrated for the period 1994-1996, we acknowledge some inconsistency. However, since our focus is on the importance of various margins impacted by housing policy, we do not feel this inconsistency is a major problem.

evaluate the performance of the model. In this section, we examine whether the model generates reasonable patterns of participation in the owner-occupied market, housing consumption, and financial portfolio decisions. A starting point is to inquire whether the model generates a reasonable homeownership rate.[25] Since the aggregate homeownership rate is a target in the estimation problem, we can check to see if the model generates a reasonable amount of "first-time buyers," which we define as households owning a home and being under the age of 35. Data indicates that 37.2 percent of households in this age cohort are homeowners. The model generates a participation rate of 37.5 percent. In Table 2, we present the homeownership rate across the age and income distributions. As can be seen, the observed homeownership rate has a hump-shaped behavior with the highest rate occurring in the 65-74 age range. The model generates a very similar pattern. It should be pointed out that the under-prediction of the oldest cohort is a result of the assumption that households must rent in the final period. Data indicate that the homeownership rate rises with income, and the model generates a similar profile. However, the profile generated by the model is steeper.

Table 2: Homeownership Rates by Age and Income

Variable				**Homeownership Rate**			
by Age Cohorts	**Inflation Rate**	**Total**	**20-34**	**35-49**	**50-64**	**65-74**	**75-89**
Data 1994		64.0	37.2	64.5	75.2	79.3	77.4
Baseline Model	0.0%	63.7	37.5	76.5	86.4	91.3	66.5
	2.4%	64.0	37.0	77.5	87.0	92.3	68.0
by Income Quintiles			**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Data 1994			46.6	56.1	64.4	75.5	89.1
Baseline Model	0.0%		52.0	89.8	97.7	99.0	100.0
	2.4%		32.5	73.6	94.2	100.0	100.0

Data source: Housing Vacancies and Homeownership (CPS/HVS) and American Housing Survey (AHS)

Another dimension of interest is the consumption of housing services. We measure average consumption of housing services by computing the average size of an owner-occupied house. Data from the *American Housing Survey* (AHS) finds the average owner-occupied house is 2,137 square feet. Our model implies an average house size of 2,348 square feet. In Table 3, we report observed housing size by age cohorts. Housing size increases until age 65 when some downsizing begins to appear. The model captures the magnitude and the hump-shaped behavior by age groups. However, some over-prediction of house size is observed.

[25] The baseline model assumes that all homeowners use the same downpayment. The empirical evidence from the AHS suggests that repeated buyers choose downpayments close to 30 percent as opposed to the 20 percent assumed. We solve the baseline model with an additional 30 percent downpayment choice and find insignificat deviations from the baseline economy.

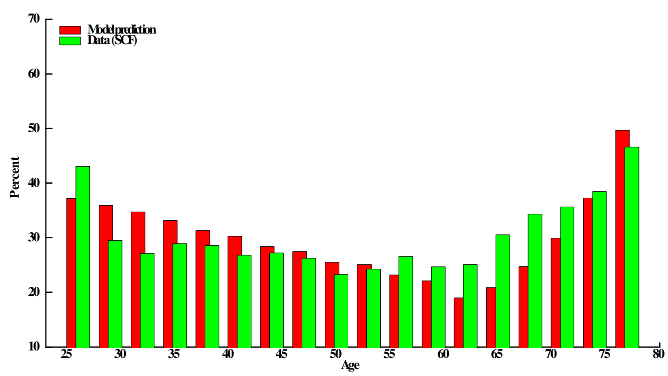
Table 3 : Owner-occupied Housing Consumption by Age[1]

Simulation	Inflation Rate	Total	20-34	35-49	50-64	65-74	75-89
Data 1994		2,137	1,854	2,220	2,301	2,088	2,045
Baseline Model	0.0%	2,348	2,147	2,297	2,429	2,514	2,362
	2.4%	2,237	2,161	2,283	2,413	2,522	2,367

Data source: American Housing Survey (AHS)

Since households make savings decisions with respect to assets, the portfolio allocations implied by the model can be analyzed. In the model, a household financial portfolio is comprised of asset holding and equity in housing investment. We use data from the 1994 *Survey of Consumer Finances* to determine the importance of housing in household portfolios. We define assets as bond and stock holdings and housing is defined as the respondent's estimated value of their house adjusted for the remaining principle.[26] The data indicate housing makes up a large fraction of a household's portfolio in the youngest age cohorts. This fraction declines as the household ages until around the retirement age, and then increases as households consume their non-housing wealth after retirement. As can be seen in Figure 1, the model generates a very similar pattern.

Figure I: Housing in the Portfolio by Age



Data source: Survey Consumer Finance (SCF)

[26] We acknowledge some inconsistency in the data and the model. The value of housing the SCF includes both the value of the structure and the value of land. Land is not accounted for in the model. Hence, the value of housing in the model reflect soley the value of the structure.

5. The Mortgage Decision

To understand the effects of the loan structure on the mortgage decision, we allow homeowners to choose between a 30-year fixed-rate contract or an alternative loan product with a different payment structure. The downpayment or loan-to- value ratio is the same for both contracts so that the effect of the repayment structure can be isolated from a pure relaxation of a borrowing constraint. We examine the various mortgage contracts in an environment where the expected inflation rate is 2.4 percent and an environment with no anticipated inflation. In our formulation all inflation is anticipated, therefore when we refer to the no inflation cases we mean no anticipated inflation. Since inflation affects the slope of the repayment structure and the nominal interest rate, an examination of both cases allows to understand the impact of anticipated inflation. Comparing mortgages in pairs has the advantage that the results are more transparent. In the experiments we maintain the parameters employed in the baseline environment. This includes the tax code parameters. Since the introduction of mortgage choice affects relative prices, revenue collection is affected. Given the focus of the paper, we abstract from the effects introduced by holding government revenue constant.[27]

5.1. The Aggregate Implications of Mortgage Choice

In order to understand the importance of the repayment schedule and terms of amortization, we examine loan products with different payment structures. We also examine a loan with a constant repayment profile, but a lower downpayment requirement to highlight differences between payment structure and downpayment requirement. The alternative contracts examined are

1. **Graduated payment mortgage (GPM):** This class of mortgage contract has the feature that nominal loan payments increase over the length of the mortgage. Contracts in this class differ in the structure of the payment schedule as well as the growth rate of the repayment schedule. A growth rate close to zero in a GPM contract is effectively a fixed rate mortgage. If a high growth rate in the repayment structure is specified, the payment structure will have a steep positive slope, and low initial payments. The tilt in the initial payments should make housing more affordable to low-income households despite the 20 percent required downpayment. In fact, this contract mimics some of the payment features of subprime contracts. We will consider a mortgage payment that grows in a constant nominal amount at a 8 percent rate.

2. **Interest-only rolled into a fixed-rate mortgage (hybrid):** A popular product in the subprime market is the so-called hybrid, payment-option adjustable, or option ARMs. This product allows borrowers a choice of several payment alternatives, ranging from full amortization of principal and interest to minimum payments in the early periods of the

[27] Otherwise, the determinants of mortgage decisions would be affected by changes in the level of taxation in the economy.

mortgage. This type of contract creates computational problems because of the amount of state variables required to keep track of the mortgage. One way to approximate this type of contract is to consider an interest-only loan that rolls into a fixed-rate mortgage after a given number of periods. Our specification considers a 12 year (four periods) interest-only loan with a 20 percent downpayment requirement that is rolled into a 18 year (six periods) FRM contract. The interest rate paid during the initial part of the loan is subject to a 150 basis-point annual premium over the baseline nominal mortgage rate.[28]

3. **Constant amortization mortgage (CAM):** The prior two contracts provide households high levels of leverage and very slow amortization. The constant amortization contract provides an alternative that allows households to accrue equity very fast and has a decreasing repayment schedule. We examine this type of contract with a 20 percent downpayment.

4. **Combo or piggyback mortgage (combo 80-20):** The previous three contracts share a 20 percent downpayment requirement. In Chambers, Garriga, and Schlagenhauf (2009), we examine a combo mortgage that employs a secondary loan to cover the downpayment requirement. With this type of contract, the household trades-off a lower downpayment at the expense of higher initial mortgage payments. The repayment structure of combo loan contracts declines over the length of the mortgage as the second loan has a shorter maturity than the main loan and an interest rate that is 200 basis points higher. Despite the higher initial mortgage payments, this product allows households that are downpayment-constrained to purchase a home. In order to highlight the role of the downpayment constraint, we also consider an 80-20 loan where households can borrow the full value of the property.

In Table 4 we present the aggregate implications of mortgage decisions.

[28] It is interesting to point out that two contracts that have played an important role in the increase in the homeownership rate in the U. S. during the period 2000-2006 are mortgage contracts that have a step function in the payment structure. These are the 80-20 contracts and the "2-28" and "3-27" contracts in the subprime market. The 80-20 product essentially uses a second mortgage to finance the downpayment, thus avoiding mortgage interest rate costs. When we examined this contract in an environment where anticipated inflation is set to zero, we find that the homeownership rate increases in the aggregate and youngest age cohorts to 65.5 and 46.1 percent, respectively. A 3-27 contract involves a three-year balloon contract that rolls into a fixed-rate contract or a floating-rate contract for the remaining 30 years. We introduced this type of contract choice into our model and find the aggregate homeownership rate increases to 70.8 percent. More startling, the homeownership rate for the youngest cohort increases to 68.0 percent. If we allow expected inflation of 2.4 percent, the results are essentially the same.

Table 4: Summary Results Mortgage Choice

Simulation	Inflation Rate	Percent Down	Ownership Rate	Housing Size Owners	Housing Size Var.	% Properties No Mortgage	Share FRM Mortgage Total
Data (AHS)		-	64.0	2,137	969	38.6	85.0
Baseline FRM	0.0%	20%	63.7	2,348	816	28.1	100.0
	2.4%	20%	64.0	2,337	805	28.2	100.0
FRM-GPM	0.0%	20%	68.5	2,351	982	1.4	45.8
	2.4%	20%	65.1	2,396	923	27.6	82.0
FRM-Hybrid	0.0%	20%	65.7	2,462	890	24.8	65.4
	2.4%	20%	70.5	2,499	1.010	8.8	63.4
FRM-CAM	0.0%	20%	65.5	2,472	904	24.9	33.9
	2.4%	20%	65.6	2,488	903	24.9	33.0
FRM-Combo 80-20	0.0%	0%	68.6	2,446	815	20.0	66.9
	2.4%	0%	66.3	2,339	807	28.2	81.3

We will initial focus on the baseline environment where the expected inflation rate is 2.4 percent. In general, the model suggests that the payment structure of a mortgage has implications for tenure decisions and the size of the homes consumed. When downpayment requirements are high (i.e. 20 percent in all contracts), households benefit from the introduction of a new mortgage loan with a variable nominal repayment structure. For example in the GPM and the hybrid contracts, both loans have an increasing nominal repayment profile that reduces the initial cost of participating in the owner-occupied housing market. The aggregate effect is an increase in the number of individuals that own homes. The magnitude of this immediate effect depends on the nominal growth rate of payments. The effect in the average size of owner-occupied housing depends on the relative opportunity cost determined in the rental markets which depend on the general equilibrium effects. The decline in the rental price (see table 5) reduces the opportunity cost of renting property and increases the average house size.

Both the GPM and hybrid-type contracts have the unattractive feature that the amortization of the principal is very slow. In contrast, a constant amortization loan structure is characterized by a declining repayment schedule and rapid amortization. With this type of loan structure, the aggregate impact on participation is relatively small when compared with other contracts. Interestingly, two thirds of the homeowners choose this product. In the presence of uninsurable labor income risk, mortgage contracts that accrued equity earlier allow some homeowners to reduce the utility cost of meeting mortgage payments every period. This precautionary motive manifests itself as an implicit preference to have equity in the property. We find that homeowers choose to purchase larger units with this type of contract.

Does expected inflation have an effect on these findings? To address this question, we examine the various mortgage contracts in an environment with no inflation. In the baseline model with only fixed rate mortgage loans the presence of inflation reduces the future value of mortgage payments but it also increases the nominal mortgage rate. With no inflation the mortgage rate is lower but the effective mortgage payments are higher in real terms. These two effects, as can be seen in Table 4, have a similar magnitude and have almost no effect the homeownership rate and house size.

The elimination of inflation highlights very interesting findings in the case of the GPM and the Hybrid loan. The absence of inflation when households have a choice between a fixed rate contract and a either a GPM or a Hybrid contract results in a larger increase in the homeownership rate and small reduction in the average home sizes. The explanation for this result lies in the general equilibrium effects on the interest rate and the rental price which are reported in Table 5. When homeowners purchase a home with a GPM mortgage, they need to anticipate an increase in future mortgage payments. In order to meet these future obligations they increase their savings, which results in a decline in the equilibrium interest rate. The absence of inflation and the low interest rates makes leverage more attractive. As a result, more than 50 percent of homeowners choose this product to purchase a house. The presence of inflation increases the mortgage interest rate but also reduces the real cost of future payments. In this environment, homeowners face a flatter repayment profile over time when compared to the case with no inflation and, thus, can save less. The lower level of savings results is high interest rate making the GPM loan less attractive as only 18 percent of the homeowners opt for this product.

The introduction of a hybrid mortgage contract also results in an increase in homeownership when compared to the baseline economy. However, the effects on homeownership and house size are further enhanced when inflation is positive. In this case, more households choose to purchase a house using a hybrid contract instead of a fixed rate contract. The repayment structure of the hybrid loan is a step function with an initial interest -only portion and no amortization that roles into a FRM with positive amortization. During the part of the contract that only requires interest payments homeowers increase their savings in anticipation of the larger future mortgage payments. The additional savings reduces the equilibrium interest rate by 10 percent and makes both products - FRM and hybrid - more attractive. This is why the decline in the share of FRM is relatively small. In the absence of equilibrium effects, the introduction of inflation would not result in as large a positive impact on ownership since interest payments would be more expensive.

In the case of the CAM the presence of inflation seems to have a very small role. The intuition behind this result is very simple. Inflation makes the payment structure of the FRM to decline over the length of the loan. The CAM loan also has a negative slope, so all it matters for mortgage choice is the relative slope and how fast is equity accrued. The presence of inflation does not have a sizeable impact in the interest rate and the relative attractiveness of each product.

The combo or piggyback loan with zero downpayment provides an interesting alternative to loans with increasing payment structure, slow amortization, and high downpayments (GPM and hybrid). The introduction of a zero down loan has a positive effect on ownership. This effect is much larger in the absence of inflation, suggesting that innovations in housing finance which relax downpayment constraints are more likely to have positive effects when inflation is low.

In general, these experiments suggest that either the repayment profile of the loan, a decline in the downpayment, or a combination of both results in similar quantitative ways to increase participation in owner-occupied housing. The presence of anticipated inflation can impact the efficacy of various contracts via general equilibrium effects. It should be stressed that the importance of the loan structure has often been ignored. The standard model used to analyze housing uses one-period-ahead mortgages where only the downpayment constraint affects tenure decisions. Our model suggests that high downpayments can be overcome with changes in the loan structure that deviate from the standard FRM contract and stable monetary policy.

The introduction of mortgage decisions with nontraditional loan products reveals interesting patterns in the number of properties that are owned free and clear of mortgage obligations. With steep repayment schedules or no downpayment requirements, the fraction of housing units without mortgages declines. Anticipated inflation magnifies this result. Between 1993 and 2005, the *American Housing Survey* reports a decline in the downpayment ratio and a decrease in the use of fixed-rate contracts. Over the same period, the fraction of homeowners with no contracts fell from 40 percent to 33 percent. We also find that when contracts other than the fixed-rate contract are available, a significant fraction of households would choose a different loan product. This is especially true in contracts with high levels of leverage and fast amortization.

Table 5: Percentage Change Aggregates

Contract Type	Inflation Rate	Rental Price	Interest Rate	Residential Investment	Housing Stock
FRM-GPM	0.0%	-5.0	-11.7	9.9	5.7
	2.4%	-2.8	0.6	2.7	3.9
FRM-Hybrid	0.0%	–3.1	-0.2	2.0	3.0
	2.4%	-5.7	-9.9	17.1	15.7
FRM-CAM	0.0%	-2.7	2.2	2.5	3.5
	2.4%	-0.2	0.0	0.0	0.6
FRM-Combo	0.0%	-6.6	-3.4	4.5	5.6
	2.4%	-3.1	-1.2	2.7	2.9

In Table 5, we examine the implications of loan structure for the aggregate economy. In general, we observe, that in an environment with no inflation, an increase in the demand of owner-occupied housing results in a decline in the rental price of tenant-occupied housing. The magnitude of this decline depends on the size of the increase in ownership. For example, the GPM and combo have a similar effects on participation rate. When a GPM mortgage is the available option, the rental price declines 5 percent. When the combo loan product is the available option, rental prices declines 7 percent. Interestingly, the model's predictions seem to be consistent with the observed decline of the relative price of tenant-occupied housing in the United States during the past decade. The effect on the interest rate depends on the number of deposits in the financial intermediary and the resources used in housing finance. The total amount of deposits depend the level of savings of renters and homeowners. Renters face a lower relative price for tenant-occupied housing and tend to increase their savings. The effect on homeowners is ambiguous. For example, when the current mortgage payment is below (above) the average payment, homeowners increase (decrease) their savings. In general, nontraditional loans have a relatively small impact in the interest rate. To explore the sensitivity of the equilibrium results, we solve the model assuming global capital markets and fix the interest rate to the baseline level. The model predicts quantitatively smaller effects in the participation rates and housing consumption. For example, in the GPM loan the model predicts an increase of 66.7 percent instead of 68.5 percent and 67.6 percent versus 68.6 percent in the combo loan. The model is also consistent with the observed increase in residential investment. The increase in the housing stock is responsible for the effects in residential investment. The size of the increase depends on the characteristics of the loan structure and the downpayment requirements.

The effect of positive anticipated inflation, in general, lessens the aforemented findings. The primary exception occurs when homeowners have access on an interest only loan that rolls into a FRM contract. As we have already discussed, household move to the interest-only loan product. The saving that occur from lower real interest payments and no principal payments are invested. The result is a lower real equilibrium interest rate, and a large increase in residential investment and the housing stock.

It is important to remark that some of the aggregate effects are the result of not adjusting government expenditures across experiments. This choice is motivated by the fact that we are interested in the equilibrium effects associated with changes in the loan structure. Adjusting the tax rate to generate the same level of revenues would obscure the direct impact of the aforementioned changes. However, it is important to mention that the changes in aggregate revenue are relatively small and are the result of changes in relative prices (wages, interest rates, and the rental price). Given this assumption, we choose not to report welfare across the experiment. The paper's objective is to understand the effects of the loan structure on the determinants of mortgage choice and not the welfare benefits associated with the additional choice of mortgage loan products.

5.2. Distributional Implications of Mortgage Choice

More can be learned about mortgage contracts by examining the implications of alternative payment structures from a distributional perspective. In particular, we focus on the implications of alternative payment structures for mortgage holdings and participation rates by age and income. This allows the attractiveness of these products to be identified for different types of households. The distributional implications are summarized in Tables 6 and 7.

Table 6: Age Cohort Effects of Mortgage Type

Contract Type	Inflation Rate	Home Ownership Rate					Percent Holding FRM				
		20-34	35-49	50-64	65-74	75-89	20-34	35-49	50-64	65-74	75-89
Baseline FRM	0.0%	37.5	76.5	86.4	91.3	66.5	100	100	100	100	100
	2.4%	37.0	77.5	87.0	92.3	68.0	100	100	100	100	100
FRM-GPM	0.0%	55.3	78.2	77.3	82.7	73.3	45.0	47.3	45.6	40.8	52.3
	2.4%	38.7	78.7	87.6	93.6	67.0	63.0	87.8	92.6	76.9	98.3
FRM-Hybrid	0.0%	39.2	80.9	87.8	92.4	65.7	31.1	72.6	82.8	70.9	90.0
	2.4%	52.1	83.7	85.7	87.3	69.2	53.3	77.2	72.6	49.6	65.8
FRM-CAM	0.0%	38.6	79.6	88.7	93.6	67.1	58.3	28.3	18.1	30.9	21.5
	2.4%	37.3	78.3	86.8	92.5	68.0	58.4	28.6	18.2	30.9	21.6
FRM-Combo 80/20	0.0%	47.2	82.9	85.3	91.0	66.3	55.1	73.2	76.7	57.4	64.2
	2.4%	40.0	80.9	89.8	90.6	67.7	62.9	87.4	92.2	69.9	98.8

Consistent with the logic of the previous section, the model reveals that mortgage loans that track household income early in the life-cycle have a significant impact on the participation rate of younger cohorts. However, this effect is muted as anticipated inflation increases over all contract, with the exception being the hybrid contract. In the case of the GPM loan, the effect is particularly large even with a 20 percent downpayment requirement. The absence of inflation makes the repayment profile steeper and more attractive for young cohorts when compared to the baseline model. One might expect that the option of choosing a mortgage loan with a payment structure that tracks income growth would increase the participation rate for all households over the age distribution. We find that this is not necessarily the case for loans with a steep repayment profile (GPM) when inflation is zero or very low. The steep increase in mortgage payments can make it financially infeasible for homeowners that have received a series of negative income shocks and face increasing payment obligations. The presence of inflation lessens this effect as the real value of future mortgage obligations are reduced. We find a positive relation between the profile of repayment (not reported in the table) and the participation of young cohorts. The combo loan trades-off a low downpayment at the expense of high initial mortgage payments. The presence of inflation increases the initial costs of the outstanding mortgage debt since the mortgage rate is higher. The result is that inflation makes the product relatively less attractive for first-time buyers.

The model indicates that the fraction of individuals holding the FRM increases with age, but the profile is not necessarily monotone, as the retirement break seems to cause a reset in the fraction of individuals holding each product. This is due to two factors. First, income uncertainty disappears for retired households even though mortality risk become more predominant at older ages. Second, retired individuals have lower income levels, making additional leverage a form of insurance.

In sum, the model suggests a certain separation of mortgage choice. Younger households tend to have low income and wealth making it difficult to smooth negative shocks. As a result, they tend to choose a loan with either a low initial mortgage payment or a low downpayment. Households that expect to receive positive income shocks or have larger asset holdings tend to choose contracts that increase their equity in the home. This result is related to the fact that average income increases over the life-cycle, even for individuals that receive negative shocks. This finding indicates loan structure has different effects for constrained and unconstrained homeowners. The results become clearer when we explore mortgage choice by income groups.[29]

Table 7: Income Distribution Effects of Mortgage Type

Contract Type	**Inflation Rate**	**Home Ownership Rate**					**Percent Holding FRM**				
		Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Baseline FRM	0.0%	52.0	89.8	97.7	100	100	100	100	100	100	100
	2.4%	32.5	73.6	94.2	100	100	100	100	100	100	100
FRM-GPM	0.0%	59.8	79.3	99.2	100	100	46.0	29.1	76.7	100	94.8
	2.4%	54.2	92.0	96.7	98.7	100	82.0	96.5	51.9	100	94.8
FRM-Hybrid	0.0%	54.9	91.5	97.8	100	100	64.1	85.7	51.7	100	100
	2.4%	61.8	85.7	78.4	100	100	67.8	36.0	82.7	100	100
FRM-CAM	0.0%	54.6	93.8	97.5	100	100	33.4	20.7	61.2	14.7	0.0
	2.4%	56.6	91.6	97.3	100	100	33.1	23.2	60.0	15.2	0.0
FRM-Combo	0.0%	58.9	88.0	96.2	100	100	68.3	50.3	68.9	99.8	95.6
	2.4%	57.6	89.9	87.1	94.2	100	81.9	92.0	36.3	100	100

There are three important results in Table 7 that summarize the effects of the loan structure on mortgage choice by income. First, the option of using a contract with either low initial mortgage payments or a higher loan-to-value ratio has a positive impact on the participation rate of the lowest income group when compared with the baseline model. This conclusion is independent of the degree of inflation. The presence of inflation reduces the increase in participation for the lowest income group in all cases with the exception of the hybrid case where strong general equilibrium effects are present. Second, the majority of individuals in the two highest income groups prefer loans that maximize the equity in the house like the traditional FRM or the constant amortization product. This result, which does not depend on whether anticipated inflation is positive, is most apparent when the CAM loan is available as an option to the FRM. Third, the decline in participation for the second income group in the GPM with no inflation as compared with the baseline case is consistent with the drop in participation by age observed in the prior table and is directly related to the rise in mortgage payments. Households are attracted to these products because of the low initial mortgage cost; however, those that receive negative income shocks cannot afford the higher payments and are forced to sell their property. The presence of inflation eliminates this effect since the real value of the mortgage payment is less.

These results reveal that some of the nontraditional products can successfully increase participation of young and poorer households in the short-run, but can cause some visible swings in the participation rate by age and income over a longer term. As the effects of idiosyncratic uncertainty are mitigated over the life-cycle (the fraction of borrowing-constrained households

[29] The income partitions have been calculated by splitting the range of income in five bins and assigning individuals of a given income level associated with the implied bin. As a result, the fraction of individuals participating in each bin is not the same. The model predicts that the majority of the individuals belong to the lowest income bins.

falls after age 40), these individuals can use the same contracts to re-enter the owner-occupied market, keeping the aggregate ownership from falling. This finding suggests that nontraditional contracts introduce very interesting dynamics in the patterns of buying and selling. To illustrate the effects of nontraditional products in the market, we present some summary measures of housing transactions in Table 8.

Table 8: Summary Measures for Housing Transactions

	Interest	Homeowners			Entry, Exit, and Stay		
Contract Type	**Rate**	**Move**	**% Upsize**	**% Downsize**	**Rent to Own**	**Own to Rent**	**Rent to Rent**
Baseline FRM	0.0%	1.7	97.0	3.0	6.0	1.5	34.8
	2.4%	1.6	99.0	1.0	6.1	1.6	34.4
FRM-GPM	0.0%	13.7	47.3	52.7	18.9	23.5	12.6
	2.4%	2.9	84.0	16.0	6.4	1.8	33.0
FRM-Hybrid	0.0%	3.5	85.5	14.5	6.5	1.9	32.4
	2.4%	12.7	41.3	58.7	15.6	10.9	18.6
FRM-CAM	0.0%	3.9	82.1	17.9	6.5	2.0	32.5
	2.4%	3.9	82.3	17.7	6.6	2.0	32.4
FRM-Combo	0.0%	8.9	63.6	36.4	11.0	6.4	25.0
	2.4%	2.9	73.7	25.3	6.7	2.2	31.5

This table presents statistics on the fraction of homeowners who choose to change their housing status, as well as statistics that measure entry and exit decisions. We find two important insights in the absence of inflation. First, the introduction of nontraditional loans - those with low initial payments, low downpayments, or both - have an important impact on mobility. The GPM and the combo loan, to a lesser extent, stand out as the fraction of homeowners who move is much greater than that observed with the other loan contracts. These products increase the mobility in the housing market, and increase the probability of downsizing. This suggests that some households purchase large housing units given the relatively low initial financing costs. However, those individuals that cannot afford the increase in mortgage obligations are forced to downsize or sell. This leads to the second important finding. In the baseline model there is a relation of around 4 to 1 between households that move into ownership and households who sell their house and rent. When nontraditional loans are available, this relation becomes almost 1 to 1, indicating much more mobility. In addition, the number of individuals that remain continuous renters decreases with nontraditional contracts. These results are consistent with the observation that the loans with low entry costs, are very successful in attracting relatively young and low-income households to the owner-occupied housing market.

The presence of inflation does effect the above conclusions. The increased mobility that was observed with GPM or Combo products is significantly reduced. The increase in the nominal mortgage rate that results in a higher monthly payment reducing the number of households who move from being a renter to a homeowner. The presence of inflation reduces the real value of mortgage obligations and implies less mobility from the homeowner status to the renter status. While inflation does impact mobility between the renter and homeownership states, one should not conclude that mobility within the homeownership state is impaired. Table 8 indicates that for the GPM or Combo cases upsizing is increased while downsizing is decreased. The presence of inflation reduces the real value of the mortgage payment and the outstanding loan overtime. This makes it easier for a household to upsize their house and lessens the need to downsize their house.

The case of the hybrid loan requires a special comment as household behavior is different in the presence of inflation. Many household, especially households that are young or have low incomes, choose the hybrid loan because of the interest-only portion of the loan. When the interest-only loan rolls into a fixed rate mortgage, the model indicates two things can happen. Poorer household's may be forced to sell their house as they may not be able to afford the increase in mortgage obligations, or downsize their house. The household who are more wealthy or have higher income refinance and upsizing their housing position using a standard FRM.

5.3. Risk Sharing Implications of Mortgage Choice

In economies with incomplete markets and long-term mortgage loans changes in loan structure have interesting effects on risk sharing that differ from the standard durable good model with a one-period-ahead collateralized loan.[30] In the standard model, individuals can mitigate labor income risk by changing house size to help smooth consumption. This is possible because the financial obligations do not have long-term effects. In models with long-term contracts, the decision to purchase a house results in the obligation of a mortgage payment. Consequently, the house payment reduces disposable income and, in the presence of negative income shocks, individuals lose part of the ability to smooth consumption.[31] Loans with different repayment structure introduce more flexibility to mitigate income risk and/or accumulate wealth. For some wealthy individuals with positive income shocks, this implies contracts that maximize the equity in the house. For young and low-income households, the optimal choice of a contract is one with increasing payment over the length of the mortgage or higher loan-to-value ratios. The result should be a reduction in the variance of consumption for homeowners, but not necessarily in the variance of housing since some of these mortgage loans force some individuals in and out of the housing market.

We study these effects by computing the coefficient of variation of consumption and housing services for the various mortgage contracts. In Table 9, we see that the benchmark economy, with no anticipated inflation, generates a coefficient of variation of consumption that is 0.113 with renters having a larger coefficient than homeowners. Our measure of variance indicates that the consumption of housing services is 0.487, with renters once again having a larger variance compared with owners. If anticipated inflation is 2.4 percent, the coefficient of variation of consumption declines to 0.109 while the coefficient of variation for homeowners declines and increases for renters. By themselves these numbers do not have much meaning since they

[30] We have in mind a model where there are no transaction costs and housing wealth, ph', and financial wealth, $(1+r)a'$, can be summarized by a single-state variable such as cash on hand $x' = ph' + (1+r)a'$ and where the period budget constraint is defined by $c + ph' + a' = w + x$ and the mortgage constraint is $a' \geq -(1-\chi)ph'$.

[31] In our model, ownership provides an alternative mechanism to smooth consumption. Homeowners can pay a fixed cost and supply rental property in the market. They can use the additional rental income to cover the cost of mortgage payments. However, this mechanism is costly.

depend on the measurement unit, but the relative numbers indicate whether new contracts allow households to better smooth consumption.

Table 9: Effects of Mortgage Choice on Risk Sharing

	Inflation	Coefficient of Variation					
		Consumption			Housing		
Simulation	Rate	Total	Owner	Renters	Total	Owner	Renters
Baseline FRM	0.0%	0.113	0.088	0.293	0.487	0.291	3.130
	2.4%	0.109	0.083	0.315	0.455	0.265	3.347
FRM-GPM	0.0%	0.098	0.077	0.160	0.466	0.264	1.400
	2.4%	0.120	0.091	0.347	0.451	0.257	3.729
FRM-Hybrid	0.0%	0.114	0.085	0.354	0.506	0.295	3.946
	2.4%	0.11	0.086	0.220	0.390	0.210	2.070
FRM-CAM	0.0%	0.110	0.084	0.336	0.482	0.290	3.578
	2.4%	0.113	0.084	0.357	0.477	0.281	3.821
FRM-Combo	0.0%	0.110	0.085	0.274	0.384	0.200	3.035
	2.4%	0.102	0.075	0.265	0.439	0.256	2.599

As can be seen, loan structure can reduce the coefficient of variation of consumption for homeowners. This reduction is especially important for contracts that allow for a steep profile of repayment (GPM) and anticipated inflation is near zero. An anticipated inflation rate of 2.4 percent actually results in an increase in the consumption coefficient for all households, but it reduces the coefficient of variation of housing services for homeowners. The reduction in the variability of consumption for this type of contract for renters when there is no anticipated inflation is an artifact of the general equilibrium effects that reduce the equilibrium price of rental-occupied housing. We also observe that the contracts that result in a larger number of transactions in the housing market, such as the hybrid and combo contracts, can result in smoother consumption of housing services if anticipated inflation is near zero. However, as anticipated inflation increases, this finding becomes more tenuous. The sizeable entry and exit decisions observed in the GPM allow households to reassess the optimal house size and thus reduce consumption of housing services. The difference in the coefficient of variation between goods and housing services consumption is a result of the preference specification that assumes imperfect substitution between both goods. When income increases over the life-cycle, the household increase spending on housing services. This explains why in the hybrid contract case with no anticipated inflation, the coefficient of variation with respect to consumption is reduced, while the coefficient of variation with respect to housing increases slightly.

6. Conclusion

Historically, it appears that innovations in housing finance have preceded important booms in housing in the United States. These innovations have modified the characteristics of the loan structure by changing the profile of repayment and amortization schedules. The recent meltdown in the subprime mortgage market further highlights the important role played by housing finance and loan structure. Unfortunately, there is limited research that examines this connection. In the canonical model with complete markets, the determinants of mortgage choice are irrelevant.

Evidence indicates that households are subject to constraints that are not fully captured by this stylized framework. The objective of this paper is to understand the effects mortgage choice has over alternative contract structures in an economy with incomplete markets. We argue that the importance of the loan structure has often been ignored in the literature that focuses on the relaxation of downpayment constraints. With this purpose, we develop a quantitative equilibrium theory of mortgage choice. In the model, households face uninsurable mortality and labor income risks and make decisions with respect to consumption (goods and housing services) and asset allocation (capital and risky housing investment). The model stresses the dual role of housing as a consumption and risky investment good. Investment in housing differs from investment in real capital since it requires a long-term mortgage loan that differs along several dimensions (downpayment requirement, payment schedule, and amortization). Thus, the model allows for mortgage contract choice.

We show that the loan structure has important implications for tenure decisions and the size of the homes consumed. When the downpayment requirement is high, households benefit from the introduction of loan products with a variable nominal repayment structure. An increasing repayment loan structure increases the participation in the owner-occupied market since it reduces the entry costs. By contrast, a decreasing repayment structure shifts the demand away from the fixed-rate mortgage loan since as homeowners are able to maximize the equity in their house. We argue that either the repayment profile of the loan, a decline in the downpayment, or a combination of both results in similar quantitative ways to increase participation in owner-occupied housing. The presence of inflation reduces real payments over the length of the loan. In general, we find that mortgage loans with variable payments are more effective when inflation is low. The structure of a mortgage has an important impacts on mobility. The presence of inflation reduces the real value of the mortgage payment and the outstanding loan overtime making it easier for a household to upsize their house and lessens the need to downsize their house.

From a disaggregate perspective, the option of using a contract with either low initial mortgage payments or a higher loan-to-value ratio has a positive impact on the participation rate of the lowest income group when compared with the baseline model. This conclusion is independent of the degree of inflation. The presence of inflation reduces the increase in participation for the lowest income group in all cases with the exception of the hybrid case where strong general equilibrium effects are present. Second, the majority of individuals in the two highest income groups prefer loans that maximize the equity in the house such as the traditional FRM or the constant amortization product. This finding is not impacted by inflation. Third, the presence of inflation mitigates some of the negative effects of increasing mortgage payments since its real value declines over the length of the loan.

In economies with incomplete markets, the payment structure of a long-term mortgage contract can provide opportunities for households to smooth income risk. The resulting decisions of homeowners has general equilibrium price effects which has beneficial effects for renters. We argue that loan structure can reduce the coefficient of variation of consumption for homeowners.

This reduction is especially important when we consider mortgages with an increasing repayment structure and no inflation. The presence of inflation reduces the coefficient of variation of housing services at the expense of goods consumption.

Given the complexity of the problem, we view these results as evidence that housing finance is an important channel that requires further analysis. Our study of the determinants of mortgage choice in a model with heterogeneous consumers and incomplete markets is subject to certain limitations. In our model, homeowners that cannot afford to meet the payments without violating the non-negativity constraint in consumption are forced to sell. However, this finding suggests a model that allows foreclosures when equity is less that the remaining mortgage debt could be useful in understanding episodes of housing default. This is especially true in an environment with stagnant or declining house prices. We have also abstracted from the implications of mortgage choice in house prices. In addition to housing finance, the dynamics of house prices are affected by many other relevant variables such as the supply of new construction and productivity growth, just to name two. While this connection is certainly important - at least some preliminary evidence from the housing booms in the past century seem to suggest it - we leave this channel for future research.

References

[1] Alm, J., and Follain J. (1984). "Alternative Mortgage Instruments, the Tilt Problem and Consumer Welfare," *Journal of Financial and Quantitative Analysis*, 19, 113-126.

[2] Berkovec J., and Fullerton D. (1992). "A General Equilibrium Model of Housing, Taxes and Portfolio Choice," *Journal of Political Economy*, 100, 390-429.

[3] Campbell, J. (2006). "Household Finance," *Journal of Finance*, 61, 1553-1604.

[4] Campbell, J., and Cocco, J. (2003). "Household Risk Management and Optimal Mortgage Choice," *Quarterly Journal of Economics*, 117, 1449-1494.

[5] Chambers, M., Garriga C., and Schlagenhauf, D. (2009). "Accounting for Changes in the Homeownership Rate," *International Economic Review*, forthcoming,

[6] Chambers,M., Garriga C., and Schlagenhauf, D. (2007). "The Tax Treatment of Homeowners and Landlords," Working Paper, Florida State University.

[7] Chan, S. (2001)."Spatial Lock-in: Do Falling House Prices Constrain Residential Mobility?," *Journal of Urban Economics*, 19, 567-586.

[8] Cooley, T. and Prescott, E.C. (1995). "Economic Growth and Business Cycles," in T. F. Cooley, ed. *Frontiers of Business Cycle Research* (T. F. Cooley, ed), Princeton, N.J.: Princeton University Press, 1-38.

[9] Díaz, A. and Luengo-Prada, M. (2008). "Durable Goods and the Wealth Distribution," *International Economic Review*, forthcoming.

[10] M. Davis and Heathcoate, J. (2005). "Housing and the Business Cycle," *International Economic Review*, 46, 751-784.

[11] Dunn, K., and Spatt, C. (1985). "An Analysis of Mortgage Contracting: Prepayment Penalties and the Due-on Sales Clause," *Journal of Finance*, 40, 293-308.

[12] Fernández-Villaverde, J. and Krueger, D. (2005). "Consumption and Savings over the Life-Cycle: How Important are Consumer Durables?," Working Paper, University of Pennsylvania.

[13] Follain, J. (1990). "Mortgage Choice," *American Real Estate and Urban Economic Associations Journal*, 43, 125-144.

[14] Gouveia, M. and Strauss, R. (1994). "Effective Federal Individual Income Tax Functions: An Exploratory Empirical Analysis," *National Tax Journal*, 47, 317-39.

[15] Gervais, M. (2002). "Housing Taxation and Capital Accumulation," *Journal of Monetary Economics*, 49 , 1461-1489.

[16] Henderson, J. V., and Ioannides, Y. (1983). "A Model of Housing Tenure Choice," *American Economic Review*, 73, 98-113.

[17] Jeske, K. (2005). "Macroeconomic Models with Heterogenous Agents and Housing," *Federal Reserve Bank of Atlanta Economic Review*, 39-56.

[18] Jeske, K. and Krueger, D. (2005). "Housing and the Macroeconomy: The Role of Implicit Guarantees for Government-Sponsored Enterprises," Federal Reserve Bank of Atlanta working paper.

[19] Kearl, J. (1979). "Inflation, Mortgages, and Housing," *Journal of Political Economy*, 87, 1115-1138.

[20] LeRoy, S. (1996). "Mortgage Valuation under Optimal Repayment," *Review of Financial Studies*, 9, 817-844.

[21] Li, W. (2005). "Moving Up: Trends in Homeownership and Mortgage Indebtedness," *Federal Reserve Bank of Philadelphia Business Review*, 26-34.

[22] Li, W., and Yao, R. (2007). "The Life-Cycle Effects of House Price Changes," *Journal of Money, Credit and Banking,* 39, 1375-1409.

[23] Määttänen, N. (2004). "On the Distributional Effects of Taxing Housing," Working Paper, Universitat Pompeu Fabra.

[24] Nakajima, M. (2003). "Rising Prices of Housing and Non-Housing Capital and Rising Earnings Instability: The Role of Illiquidity of Housing," Working Paper, University of Pennsylvania.

[25] Ortalo-Magne, F., and Rady, S. (2006). "Housing Market Dynamics: On the Contribution of Income Shocks and Credit Constraints," *Review of Economic Studies*," 78, 459-485.

[26] Ríos-Rull, J.V. (1996). "Life Cycle Economies and Aggregate Fluctuations," *Review of Economic Studies,* 63, 465-489.

[27] Ríos-Rull, J.V. (2001). "Population Changes and Capital Accumulation: The Aging of the Baby Boom," *The BE Journal of Macroeconomics*, 1, art7.

[28] Ríos-Rull, J.V., and Sanchez-Marcos, V. (2006). "An Aggregate Economy with Different House Sizes," Working paper, University of Pennsylvania.

[29] Sanchez, J.-M. (2007). "An Estimable Dynamic Model of Housing Tenure Choice," Working Paper, Instituto de Economía, Pontificia Universidad Católica de Chile.

[30] Shilling, J.D., Dhillon, U. and Sirmans, C. (1987). "Choosing Between Fixed and Adjustable Rate Mortgages," *Journal of Money, Credit and Banking*, 19, 260-267.

[31] Stanton, R., and Wallace, N. (1998). "Mortgage Choice: What's the Point?," *Real Estate Economics*, 26, 173-205.

[32] Storesletten, K., Telmer, C. and Yaron, A. (2004). "Consumption and Risk Sharing over the Life Cycle," *Journal of Monetary Economics,* 51, 609-633.

[33] Tauchen, G. (1986). "Finite State Markov Chain Approximation to Univariate and Vector Autoregressions," *Economic Letters*, 20, 177-181.

7. Appendix: Definition of Recursive Stationary Equilibrium

We restrict ourselves to stationary equilibria. The individual state variables are asset holdings, a, housing investment holdings, h, mortgage contract type, z, mortgage status, n, labor productivity status, ϵ, and age,j. The individual state of the economy is completely described by the joint measure Φ over asset positions, housing investment positions, mortgage contract type, mortgage status, productivity state, and age, where $\Lambda = (a, h, z, n, \epsilon, j)$. Let $a \in \mathcal{A} \subset \mathbb{R}_+$, $h \in \mathcal{H} \subset \mathbb{R}_+$, z$\in \mathcal{Z} \subset I, n \in \mathcal{N} = (1, 2, ..., N) \in I$, $\epsilon \in \mathcal{E} = \{\epsilon_1, \epsilon_2, \epsilon_3, \epsilon_4, \epsilon_5\} \subset I$, $j \in \mathcal{J} = (1, 2, ..., J) \subset I$, and let $\mathcal{S} = \mathbb{R}_+ \times \mathbb{R}_+ \times \mathcal{Z} \times \mathcal{N} \times \mathcal{E} \times \mathcal{J}$.

Definition (Stationary Equilibrium): Let us define I_s to be an indicator function that is equal to one when a housing investment position is sold and zero otherwise. Given a set of time-invariant fiscal policy arrangements $\{G, \tau_y(\eta_0, \eta_1, \eta_2), \tau_p(\overline{\theta})\}$, and initial conditions, *a stationary equilibrium is a collection of value functions,* $v(a, h, z, n, \epsilon, j,)$: $\mathcal{A} \times \mathcal{H} \times \mathcal{Z} \times \mathcal{M} \times \mathcal{E} \times \mathcal{J} \to \mathbb{R}$; *and decision rules for the household,* $\{a', h', z', c, d : S \to \mathbb{R}_+\}$ if $\mathrm{I}_s = 0$ or $\{a'_\xi, h'_\xi, z'_\xi, c_\xi, d_\xi : S \to \mathbb{R}_+\}$ if $\mathrm{I}_s = 1$, aggregate outcomes $\{K, N\}$; *prices* $\{r, p, R, r^m\}$; *stationary population and invariant distribution* $\Phi(a, h, z, n, \epsilon, j)$ *such that*

1. *Given prices, $\{r, p, R, r^m\}$, policies, transfers, and initial conditions, the value function v and decision rules c, s, a', and h' solve the consumer's problem as specified in equations (3.3), (3.4), (3.5), (3.6), and (3.7).*

2. Transfers are defined in equation (3.10).

3. The asset market as defined by equation (3.12) clears.

4. The rental market as defined by equation (3.13) clears.

5. The goods market condition is defined as

$$C + K' - (1-\delta)K + I_H + G + \Upsilon = F(K, N),$$

where C, $K' - (1-\delta)K$, I_H, G, Υ represent aggregate consumption expenditures, aggregate investment in fixed capital, aggregate investment in housing goods, government expenditure, and aggregate total transaction costs. These variables are equal to

$$C = \int_{I_s(\Lambda)=0} \mu_j c(\Lambda)\Phi(d\Lambda) + \int_{I_s(\Lambda)=1} \sum_{\xi\in\Xi} \pi_\xi \mu_j c_\xi(\Lambda)\Phi(d\Lambda),$$

where I_H represents the investment housing goods,

$$\begin{aligned} I_H = & \int_{I_s(\Lambda)=0} \mu_j h'(\Lambda)\Phi(d\Lambda) + \int_{I_s(\Lambda)=1} \sum_{\xi\in\Xi} \pi_\xi \mu_j h'_\xi(\Lambda)\Phi(d\Lambda) \\ & - [\int \mu_j h(\Lambda)\Phi(d\Lambda) - [\delta_o(\int_{\substack{I_s(\Lambda)=0 \\ s(\Lambda)\geq h'(\Lambda)}} \mu_j h'(\Lambda)\Phi(d\Lambda) + \int_{\substack{I_s(\Lambda)=1 \\ s(\Lambda)\geq h'(\Lambda)}} \sum_{\xi\in\Xi} \pi_\xi \mu_j h'(\Lambda)\Phi(d\Lambda)) \\ & - \delta_r(\int_{\substack{I_s(\Lambda)=0 \\ s(\Lambda)<h'(\Lambda)}} \mu_j h'(\Lambda)\Phi(d\Lambda) + \int_{\substack{I_s(\Lambda)=1 \\ s(\Lambda)<h'(\Lambda)}} \sum_{\xi\in\Xi} \pi_\xi \mu_j h'(\Lambda)\Phi(d\Lambda))], \end{aligned}$$

and Υ denotes resources allocated to total transaction and fixed costs,

$$\begin{aligned} \Upsilon = & \int_{I_s(\Lambda)=0} \mu_j \phi_B h'(\Lambda)\Phi(d\Lambda) + \int_{I_s(\Lambda)=1} \sum_{\xi\in\Xi} \pi_\xi \mu_j \phi_B h'(\Lambda)\Phi(d\Lambda) \\ & + \varpi \int_{\substack{I_s(\Lambda)=0 \\ I_r(\Lambda)=1}} \mu_j \Phi(d\Lambda) + \varpi \int_{\substack{I_s(\Lambda)=1 \\ I_r(\Lambda)=1}} \sum_{\xi\in\Xi} \pi_\xi \mu_j \phi_B \Phi(d\Lambda). \end{aligned}$$

6. The labor market clears where labor demand, as determined by the firm's first-order condition, is equal to labor supply.

7. The general government balances as specified by equation (3.8).

8. The social security program is self-financing with the tax rate determined by equation (3.9).

9. Letting T be an operator, which maps the set of distributions into itself aggregation, requires

$$\Phi'(a', h', z, n-1, \epsilon', j+1) = T(\Phi),$$

with T also consistent with individual decisions. We will restrict ourselves to equilibria which satisfy

$$\Phi' = T(\Phi),$$

where the function $T : \mathcal{M} \rightarrow \mathcal{M}$.