INTERNATIONAL
ECONOMIC
REVIEW

August 2009
Vol. 50, No. 3

ACCOUNTING FOR CHANGES IN THE HOMEOWNERSHIP RATE*

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This article accounts for the boom in homeownership from 1994 to 2005 by examining the roles of demographic changes and mortgage innovations. To measure the impact of these factors, we construct a quantitative general equilibrium overlapping generation model with housing. In the long-run, mortgage innovation accounts for between 56 and 70% of the increase whereas demographics account for a much smaller portion. We test this result by considering changes in mortgages after 1940. We find that the introduction of the conventional fixed rate mortgage accounts for at least 50% of the observed increase in homeownership during that period.

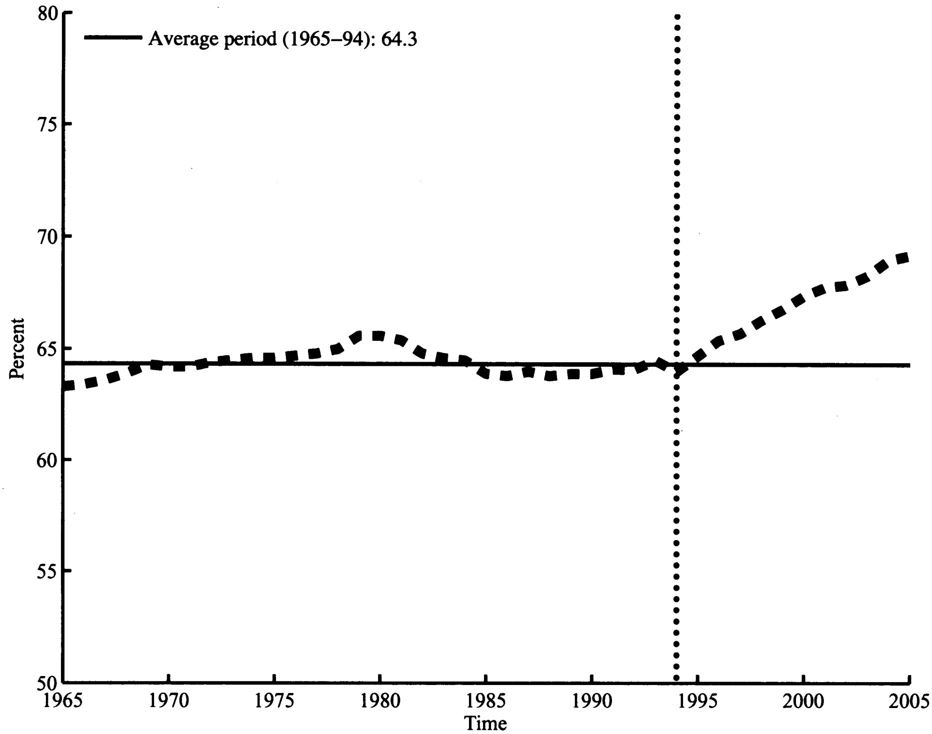
1. INTRODUCTION

The homeownership rate in the United States achieved new record highs over the period 1994–2005. In Figure 1, we present the evolution of this rate since 1965. As can be seen, the increase in homeownership is preceded by a quarter century of relatively constant rates. This leads to the question of why did the homeownership rate increase after 1994.[2] The increase in the number of housing

* Manuscript received January 2005; revised February 2008.

[1] We acknowledge the useful comments of three referees and Dirk Krueger, David Marshall, Ed Prescott, Victor Ríos-Rull, and Eric Young and the editorial assistance of Michelle Armesto and Judy Ahlers. A version of this article was presented at the 2008 NBER Economic Fluctuations and Growth Research Meeting, 2004 Annual Meetings of the Society for Economic Dynamics, Universitat Autònoma de Barcelona, Universitat de Barcelona, Iowa State University, University of Virginia, and SUNY at Stony Brook. We are grateful to the financial support of the National Science Foundation Grant SES-0649374. Carlos Garriga 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. Please address correspondence to: Don Schlagenhauf, Department of Economics, Florida State University, 246 Bellamy Building, Tallahassee, FL 32306-2180, U.S.A. Phone.: 850-644-3817. Fax: 850-644-4535. E-mail: *dschlage@mailer.fsu.edu*.

[2] The small increase in ownership during the late 1970s is consistent with the entry of the first participants of the baby boomer cohorts. However, the importance to the baby boomers' generation



NOTE: United States Statistical Abstract.

FIGURE 1

HOMEOWNERSHIP RATES FOR THE U.S: 1965 TO PRESENT

units that are owner-occupied masks interesting disaggregated changes. Between 1994 and 2005, much of the increase in the aggregate homeownership can be attributed to households of age 35 years and under as homeownership increased from 37.3 to 43% in this age group.

Given that housing policy in the United States has been directed toward enhancing homeownership through the differential tax treatment of owner-occupied housing, Government-Sponsored Enterprises such as Fannie Mae and Freddie Mac, and downpayment assistance programs, the homeownership rate is watched by both researchers and policymakers. The seemingly stationary behavior of this rate prior to 1994 could be employed as evidence of the failure of housing policy to enhance homeownership.[3] The increase in the homeownership rate since the

did not carry over during the 1980s, and the ownership rate was stagnant during this time period (Green, 1995).

[3] For instance, Glaeser and Shapiro (2002) use the constancy of the ownership rate for over 30 years to question the efficacy of the home interest rate mortgage deduction policy as a means of increasing homeownership. They argue that the deductibility of the mortgage interest and property tax payments encourages homeownership by the wealthy, who are already homeowners.

mid-1990s has been used by some policymakers to argue that recent housing initiatives are starting to have the desired effect.[4] However, any conclusions about the effectiveness of housing policy programs must consider other factors such as the demographic and institutional changes that have occurred over this period. In this article, we attempt to explain why homeownership has increased since 1994 by using a quantitative model that pays particular attention to the role of changes in demographic structure and financial innovations in the mortgage market.

To gain insight into the impact of demographic and nondemographic factors on the homeownership rate, we consider a simple expression that aggregates the participation in owner-occupied housing across households in the population. We allow households to be of different types. Within a type, all households are identical.[5] We denote a household type by $i = \{1, \dots, I\} = \mathcal{I}$, where $\mathcal{I}$ defines the number of types and μ_t^i measures the number of households of each type at time t. The fraction of type i households that are homeowners in period t is represented by π_t^i. Hence, the aggregate ownership rate in period t is simply the weighted average of the type-specific participation rates, or $\Pi_t = \sum_{i \in I} \mu_t^i \pi_t^i$. This expression allows changes in the aggregate ownership rate to be decomposed into changes in the relative size of a type, μ_t^i, and/or changes in the participation behavior of a type, π_t^i.

Changes in the demographic structure could be responsible for the growth in the homeownership rate between 1994 and 2005 if these changes occur in household types with larger participation rates. To evaluate this possibility, we calculate the aggregate ownership rate that would result under the assumption that the behavior of the different cohorts, as captured by the participation rate, remains unaltered since 1994, whereas the population structure is that observed in 2005. That is, we calculate $\sum_{i \in I} \mu_{2005}^i \pi_{1994}^i$. We find that this calculation yields an increase in the aggregate ownership rate of 1.92 basis points—a value much lower than the 5-basis point change observed in the data. This implies that around 23% of the increase in the homeownership rate could be a result of changes in the population structure whereas 77% of the increase in homeownership is left to nondemographic factors.

During this time period, important changes in nondemographic factors occurred that could affect the participation rate in owner-occupied housing. Some of these developments include the introduction of new mortgage products such as the combo loan, a reduction in the cost of providing mortgage services, an expansion of subprime lending, and the growth and development of secondary markets to accommodate the introduction of new mortgage products. For existing homeowners, the effects of these innovations should not impact the homeownership rate. These developments could change their housing investment decision, as some households might choose to refinance their existing mortgage or choose to sell their property and buy another house. In either case, the household maintains

[4] The Bush administration has argued that the increase in the homeownership rate is evidence that the American Dream Downpayment Act, which provides downpayment assistance, is working.

[5] A type allows households to be classified into different socioeconomic groups such as race, income, or age.

the status of homeowner. For those households that might have had insufficient resources to meet the downpayment or credit requirements, the effect of these financial innovations could result in an increase in the homeownership rate. For example, the introduction of a mortgage loan product that allows buyers to purchase a home with a minimum downpayment relaxes the downpayment constraint and could result in a behavior that increases the participation rate, π_t^i. Alternatively, mortgage innovation could affect the profile of repayment and the accumulation of equity in the property. The importance of these additional margins is explored in more detail in Chambers et al. (2007).

The objective of this article is to account for the observed increase in the homeownership rate and thereby understand the role played by demographic factors and mortgage market innovations. To measure the aggregate and distributional impact of these two factors, we construct a general equilibrium overlapping generations model with housing and mortgage markets. The model generates participation rates, π_t^i, that result from the household's optimal behavior. Some of the features of the model are as follows: Homeownership is part of the household's portfolio decision; life-cycle effects play a prominent role; rental and owner-occupied housing markets coexist; and households make the discrete choice of whether to own or rent as well as the choice of what quantity of housing service flows to consume. In each period, households face uninsurable mortality and labor income risks and make decisions with respect to consumption (goods and housing services) and saving (capital and risky housing investment). Hence, the model stresses the dual role of housing as a consumption and investment good. The investment in housing differs from real capital in that a downpayment and mortgage are required, changes in the housing investment position are subject to transaction costs, and idiosyncratic shocks affect sales value.[6] The model allows the flow of housing services from the housing investment to be either consumed or sold in the rental market if a fixed cost is paid.

We estimate the baseline model to match economic and demographic features observed in 1994 and conduct a detailed decomposition of factors that can account for the observed changes in the ownership rate over the last decade. Demographic changes are considered in isolation. We also consider innovations in the mortgage market such as reductions in transaction costs of buying property, decreases in downpayment requirements, and the introduction of new mortgage contracts such as the combo loan. The introduction of new mortgage products means that mortgage choice must be explicitly considered and multiple mortgage products must coexist in equilibrium. This insight is one of the contributions of the article. Finally, we explore the combined effects of demographics and mortgage innovation in accounting for the observed change in homeownership.

[6] There has been a lot of discussion about the high growth rates of house prices over the same time period. In this article, we do not seek to explain the joint movement of house price and homeownership. Despite being a limitation of the analysis, our objective is to relate aggregate quantities to changes in fundamental variables such as the demographic structure or financial innovation in the mortgage markets. The introduction of idiosyncratic capital gains has the objective of partially capturing the risk associated to investing in real estate upon the sale of the property.

We find that the importance of the introduction of a second mortgage product, from a long-run perspective, accounts for between 56 and 70% of the increase in the aggregate homeownership rate. Demographic effects account for between 16 and 31%. We show that a reduction of the downpayment requirement in an economy with only one mortgage contract does not necessarily increase ownership. The relaxation of the downpayment ratio allows households to purchase housing with larger mortgage payments, but also results in a higher interest rate. This means that in the presence of uninsurable idiosyncratic risk, households that receive negative income shocks can be forced to sell their house and rent, thus offsetting initial homeownership gains. The key to understanding the increase in homeownership is the expansion of the set of mortgage loans that vary in downpayment requirements and mortgage interest payments. We find that combo loans with minimal downpayment requirements tend to be the contract of choice for younger cohorts. Roughly 80% of the predicted increase in the participation rate for the younger cohorts can be attributed to the introduction of new mortgage instruments. Demographic changes by themselves are not able to account for the increase in the participation of these households. By contrast, demographic factors are especially important in understanding participation rate changes of households older than age 50 years. We also examine the transition path of homeownership to determine whether the importance of various factors differs from the long-run analysis. In the short run, the interaction of mortgage innovation and demographic changes results in an increase in the homeownership rate. The homeownership rate declines over time, but remains above the initial level, indicating that mortgage innovation persists. For example, in 2005, the actual homeownership rate was 69%. Along the transition path the model predicts that if only demographic factors are allowed to change, the homeownership rate for that year would be 66.3%. The combined effect of demographics and the introduction of a 5% downpayment combo loan predict a 68.5% homeownership rate for that year. In this case, demographic factors would account for 58% of the increase in homeownership. On the other hand, a zero downpayment combo loan results in an even larger increase in the homeownership rate. In this case, the importance of financial innovation increases in relative importance and accounts for 59%, whereas demographic factors only account for 41% of the total effect.

The importance of mortgage market innovations in explaining increases in the homeownership rate can be further tested by considering movements in the homeownership rate immediately after World War II. After the collapse of mortgage markets during the Great Depression, a goal of policymakers was to increase owner-occupied housing. In the later 1930s, the Federal Housing Administration (FHA) had the role of altering the forms and the terms of existing mortgage contracts. Prior to the Great Depression, the typical mortgage contract had a maturity of less than 10 years, a loan-to-value (LTV) ratio of about 50%, repayment of interest only during the life of the contract, and a balloon payment at expiration. The FHA sponsored the use of a new type of home mortgage product with a longer duration, lower downpayment requirement (i.e., a high LTV ratio), and self-amortizing with a joint repayment of the principal and interest. After World

War II, the homeownership rate increased from 48% to roughly 64% by the mid-1960s. This unprecedented growth in ownership still remains a puzzle. Rosen and Rosen (1980) find that federal tax policy accounts for approximately 4 basis points in the increase in the homeownership rate. This leaves a large fraction of the observed increase unaccounted. We use our model to examine the importance of the introduction of the standard fixed rate mortgage (FRM) during this time period by conducting a counterfactual experiment. We introduce the demographic structure from the 1940s and we restrict the set of mortgage choices to a 9-year balloon contract with a 50% downpayment. The model predicts that the aggregate homeownership rate should fall from 64% to less than 55%. These two effects combine to account for 10 basis points of the total increase. We view this counterfactual experiment as further evidence of the importance of innovations in the mortgage market.

In recent years, there have been a number of papers that have examined housing in a general equilibrium framework with heterogeneous agents. Some of these papers are Berkovec and Fullerton (1992), Díaz and Luengo-Prado (in press), Fernãndez-Villaverde and Krueger (2002), Gervais (2002), Jeske and Krueger (2005), Kiyoyaki et al. (2007), Nakajima (2003), Ortalo-Magne and Rady (2006), Platania and Schlagenhauf (2000), and Ríos-Rull and Sanchez-Marcos (2006). The focus of these papers differs from ours in that they ignore the joint role of demographics and institutional changes in mortgage instruments. The paper closest to our article is Nakajima (2003), who studies the impact of income inequality on house prices in an endowment economy with segmented markets. He finds that the observed income inequality can rationalize about one-third of the observed increase in house prices, but ignores the impact of financial innovation and demographics on homeownership. There exists another line of research that employs econometric techniques. Savage (1999) explores the barriers to homeownership and discusses how affordability might be changed by altering downpayment requirements, changing interest rates, or permitting subsidies to renters seeking to purchase a house. Segal and Sullivan (1998) find that the aging of the baby boomers, increases in educational attainment, and the growth in income all combine to increase homeownership. Gabriel and Rosenthal (2005) examine changes in the participation rate of different ethnic groups and argue that these changes can explain the observed changes in the aggregate homeownership rate. Fisher and Quayyum (2006) explore the connection between the high levels of homeownership and residential investment. As part of their study, they examine the role of changes in demographic factors. Their empirical work suggests that demographics, income, and education account for one-half of the increase in homeownership. Mortgage market innovations are not addressed in their paper.

This article is organized into four sections. The first section disaggregates U.S. ownership data to understand the nature of changes between 1994 and 2005. The second section describes the model economy and defines equilibrium, and the third section explains how we estimate the model to the U.S. economy. Section 4 discusses the parametrization and model evaluation. In the fifth section, we examine the quantitative importance of various factors that can account for changes in homeownership. In the next section, we use the housing boom immediately after

World War II to further test the importance of mortgage innovation. The final section concludes.

2. EMPIRICAL ANALYSIS OF CHANGES IN THE OWNERSHIP RATE

In this section, we use U.S. data to understand the sources of change in the aggregate ownership rate. We begin by more carefully documenting changes in the population structure and the homeownership rate since 1994. We use annual data from *Housing Vacancies and Homeownership* in the *Current Population Survey* to examine the evolution of the homeownership rate and data from the *United States Statistical Abstract* to analyze the changes in population structure. We develop in more detail the calculations described in the introduction. This analysis stresses the importance of changes in the participation rate. In order to better understand these changes, we examine movements in this rate from an age and income perspective using data from the *American Housing Survey* (AHS).

The aggregate ownership rate Π_t for a given year t can be expressed as

$$\Pi_t = \sum_{i \in I} \mu_t^i \pi_t^i,$$

where μ_t^i is the measure of households of type i in period t, and π_t^i denotes the ownership rate for individuals of type i in period t. The contribution of a factor can be roughly estimated by appropriately holding the other factors constant, and then calculating a hypothetical aggregate rate. For example, the effect of demographic changes on the homeownership rate can be estimated by holding the participation behavior of year 1994 constant and using the population structure of 2005 in the calculation of the aggregate rate. Table 1 summarizes the implied homeownership rates for different combinations of population structures and individual participation behavior.

We find that if the participation rates for the different cohorts remain at their 1994 level and allow the population structure to change to what is observed in 2005, the implied ownership rate increases by 1.2 basis points to 65.2%. This implies that demographic changes account for 23% of the 5.2 basis point increase in the homeownership rate between 1994 and 2005. Demographic changes, as

TABLE 1

UNITED STATES: ACTUAL AND HYPOTHETICAL HOMEOWNERSHIP RATE WITH RESPECT TO 1994

	Expression	Ownership Rate	Percent Change
Participation (1994) and Population (1994)	$\sum_{i \in I} \mu_{1994}^i \pi_{1994}^i$	64.0	–
Participation (2005) and Population (2005)	$\sum_{i \in I} \mu_{2005}^i \pi_{2005}^i$	69.2	8.2
Participation (1994) and Population (2005)	$\sum_{i \in I} \mu_{2005}^i \pi_{1994}^i$	65.2	1.9
Participation (2005) and Population (1994)	$\sum_{i \in I} \mu_{1994}^i \pi_{2005}^i$	68.5	7.0

NOTES: *United States Statistical Abstract* and Housing Vacancies and Homeownership (CPS/HVS).

TABLE 2

UNITED STATES: HOMEOWNERSHIP RATE BY AGE AND INCOME OF HOUSEHOLD

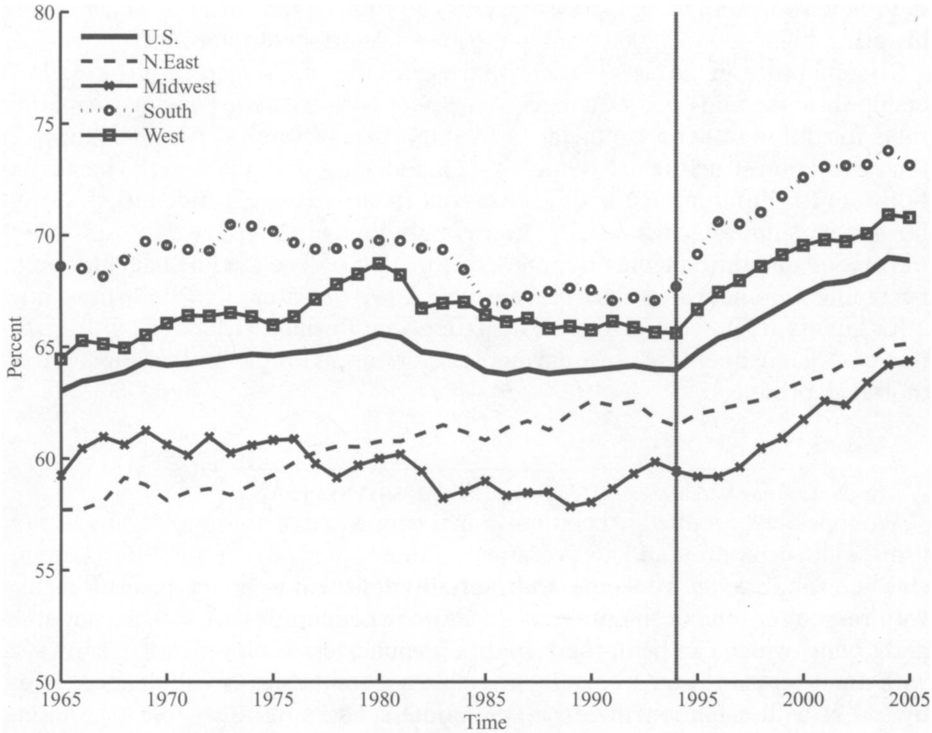
Household Age	1994	2005	Difference
Total	64.0	69.0	5.0
Less than 35 years	37.3	43.0	5.7
35 to 49 years	64.6	68.7	4.1
50 to 64 years	77.6	79.4	1.8
65 to 74 years	80.3	82.7	2.4
75 years and over	73.5	78.4	4.9
Household Income Group	1995	2003	Difference
Group 1	46.63	52.83	6.20
Group 2	56.05	67.01	10.96
Group 3	64.40	77.93	13.53
Group 4	75.54	88.78	13.24
Group 5	89.13	96.57	7.44

NOTES: Housing Vacancies and Homeownership (CPS/HVS) and AHS.

reflected in the population cohort weights, do not seem to be the primary factor in accounting for the overall increase in homeownership. In order to estimate the effect of changes in participation rates, the population structure observed in 1994 can be held constant and the participation rates set to their 2005 values. Under this set of assumptions the implied ownership rate is 68.5%. This is a 4.5 basis point increase and suggests that changing participation rates across cohorts account for 87% of the increase in the observed aggregate housing participation rate. The total effect also includes a joint effect that amounts to −0.7, which results from the combined change in population shares and participation rates. The implication of this analysis is that the answer for the increase in the homeownership rate lies in changes in cohort participation rates.

In order to get a better understanding of participation rate changes in the owner-occupied housing market, disaggregated homeownership data are examined. We focus on changes in the homeownership rate from an age and income perspective. This analysis is summarized in Table 2.

As can be seen, the homeownership rate increases in all cohorts. What is important is how the age-cohort participation rates changed between 1994 and 2005. The participation rates did not increase uniformly over the various cohorts. In fact, the largest increase in participation rates occurs in the households under the age of 35 years. Even though we observe an increase in the homeownership rate of households after age 65 years, the under-35-years age cohort finding suggests an important part of the explanation for the increase in the homeownership rate is understanding why younger households increased their participation rates. We also examine the participation rates from an income perspective. The range of income is partitioned into five equally spaced income groups with the first group representing the lowest 20% of income. When participation rates by income are examined, we find that this rate increases in each income group between 1994 and 2005. Again, the increase is not uniform over income groups. The larger changes



NOTE: Housing Vacancies and Homeownership (CPS/HVS).

FIGURE 2

HOMEOWNERSHIP RATES FOR THE U.S. AND REGIONS: 1965 TO PRESENT

are observed in the middle income groups. Since the mass of households is larger in the lower income groups, this suggests understanding the increase in participation rates in the second and third income groups is important.

Another possible factor is migration within the United States. Part of the observed increase could be explained by the rapid population growth in relatively low-cost (and thus high homeownership) states in the South or Southwest. Even in the absence of macroeconomic effects, the migration effect would create an increase in aggregate homeownership rate. This increase would occur even when the homeownership rates are stable in different housing markets. To address this issue, we present the evolution of the regional homeownership rate since 1965 to present.

Figure 2 summarizes the aggregate homeownership rate for the United States and for four distinct regions that comprised the Northeast, the Midwest, the South, and the West. Prior to 1994, the stationary pattern observed in the aggregate homeownership rate does not carry over to the regional rates. For example, in the West region, there is some slight downward trend, whereas in the Northeast region, the trend appears to be slightly increasing. However, the important observation is that the homeownership rates increased across all four regions after 1994, achieving historical highs around 2005 even in the presence of migration flows.[7]

To summarize, in the last decade we have faced the largest increase in homeownership since the mid-1960s. Changes in the population structure and participation rates for different cohorts appear to be important factors. Although changes in the population structure are relatively well understood, changes in the participation rate for different age and income cohorts are less well understood. Given how ownership rates increased in households younger than age 35 years and in the second and third income quintiles, factors that reduce the financial burden of becoming a homeowner must be considered. We use a model to illustrate how affordability might change the participation rate through reductions in transaction costs, adjustments in downpayment requirements, or the introduction of new mortgage products.

3. THE MODEL

We consider a production economy that is comprised of households, production firms, a financial firm, and a government. Households have a finite horizon and face uninsurable labor income and mortality risk. Households make decisions with respect to the consumption of goods, the consumption of housing services, and saving, which can be in the form of either riskless capital denoted by $a \in \mathcal{A}$ with a net return r, and a housing investment good, which is risky and denoted by $h \in \mathcal{H}$ with a market price p. The model stresses the dual role of housing as a consumption and investment good. Investment in housing differs from real capital since it requires a long-term mortgage contract and is subject to transaction costs. Mortgage loans are available from a financial sector that receives deposits from households and also loans capital to private firms. The production side is standard as we consider neoclassical firms that use capital and labor to produce a consumption/investment good and housing. The government has a dual role of taxing income and providing retirement benefits through a social security system. Income taxes are distortionary, especially as they pertain to mortgage finance.

3.1. *Housing Characteristics and Mortgage Contracts.* We model housing as a risky investment/consumption good. The nature of housing investment differs from investment in capital along several important dimensions.

1. **House investment size:** In this model, housing investment is lumpy and indivisible. We denote the size of the housing investment by $h \in \mathcal{H}$ where $\mathcal{H} \equiv \{0\} \cup \{\underline{h}, \dots, \bar{h}\}$ and $\underline{h} < \cdots < \bar{h}$. The lumpiness, along with transactions costs, generates infrequent adjustments in housing investment positions. The indivisibility of this investment with $\underline{h} > 0$ results in some households being unable to participate and thus forces housing services to be acquired in a rental market. If a household chooses to change their

[7] We also examined movements in the homeownership rate by family type. After 1994, married households, male households, and female households all had rising participation rates.

investment position, their existing housing investment must be sold and a new housing position purchased.[8]

2. **Housing as a risky investment:** The decision to sell property is subject to an i.i.d. idiosyncratic capital gains (or amenity) shock, $\xi \in \Xi \equiv \{\xi_1, \ldots, \xi_z\}$. The shock determines the final sale value $p\xi h$ received by the homeowner. This shock alters the size of the housing investment by a factor ξ.[9] In addition, this shock is not observed until the house is sold. Households know the unconditional probability of this event, which is represented by π_ξ.[10]
3. **Housing investment/consumption good:** Housing investment, $h' > 0$, generates a flow of housing services, s, that can be consumed. We assume a linear technology, $s = g(h') = h'$, that transforms the housing investment in the current period into housing services in the same period. In this model, homeowners derive utility from the housing services generated by the housing investment decision made in the current period, h'. This timing differs from other housing (and durable goods) models where the state variable h generates housing services within the period. The separation between housing investment and housing consumption allows us to formalize rental markets. Those households that have a positive housing investment can choose to consume all housing services $s = h'$ or pay a fixed cost $\varpi > 0$ and sell (lease) some services in the market equal to $g(h') - s$ at the rental price R.[11]
4. **Housing maintenance:** The consumption of housing services depreciates the housing investment and requires maintenance to maintain the discrete size investment position. The implied maintenance expense, $x(h', s)$, depends on the size of housing investment and whether housing services are consumed by homeowners or rented to other individuals.[12] A

[8] This assumption differs from the standard durable good model where individuals can expand the set of durables every period until they attain their desired level. In our model, households can purchase homes of different sizes, but they are forced to sell if they desire to buy a different unit. Since housing investment requires the use of a long-term mortgage contract, it becomes computationally infeasible to have households holding a housing portfolio with different mortgage balances.

[9] The idiosyncratic capital gains or amenity shock allows a risk to be associated with housing without introducing an aggregate shock that determines capital gains. Adding aggregate uncertainty is not computationally feasible in this model at this time. The amenity 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 the necessity of matching buyers and sellers is avoided, since any buyer can always purchase a home independent of the shock received by the seller.

[10] In Jeske and Krueger (2005), homeowners face a depreciation shock every period that changes the size of the housing investment position next period. Since homes are transacted every period using a one-period mortgage, homeowners readjust their portfolio every period. In our formulation, the capital gain shock is only realized upon the transaction of the property. Consequently, it does not affect the flow of services that homeowners receive every period.

[11] The introduction of the fixed cost prevents homeowners from freely using the rental market to buffer negative income shocks. This cost should be viewed as either a time opportunity cost or as a management fee. These costs are paid every period and are independent of the size of the property.

[12] Henderson and Ioannides (1983) argue that there is an externality associated with the rental of housing services. The individual who consumes the services generated by a house decides on how

homeowner that chooses to consume all services generated from her housing investment position incurs a maintenance expense equal to $x(h', s) = \delta_o\, ph'$ where δ_o represents the depreciation rate of owner-occupied housing. If a household chooses to pay the fixed cost to become a landlord, the maintenance expense depends on the fraction of services the household consumes and the fraction other households consume. The different depreciation cost is a result of a moral hazard problem that occurs in rental markets as renters decide on how intensely to utilize/depreciate a house. To illustrate the nature of the problem, we assume that households can choose two different efforts to maintain the dwelling $e \in \{e_L, e_H\}$. The depreciation rate of the housing stock depends on the effort $\delta\ (e)$. Since a homeowner understands the costs associated with utilization, an incentive exists to maintain the home, and thus she exerts (high) effort to maintain her house. When landlords cannot observe the utilization rate or maintenance efforts of tenants, they assume all renters will choose a low maintenance effort e_L. The depreciation rate associated with low effort is $\delta_r > \delta_o$. The maintenance cost of rental-occupied housing is determined as $x(h', s) = p[\delta_r h' - (\delta_r - \delta_o)s]$. The formal implications of moral hazard is a spread in depreciation rates ($\delta = \delta_r - \delta_o > 0$) that effectively reduces the implicit cost of owner-occupied consumption. This effect also introduces a kink in the consumer budget constraint on the point where households choose to consume all their housing services. The market rate for rental services will incorporate the moral hazard problem and renters have to pay a premium reflecting the additional maintenance cost.[13] Maintenance is not subject to transaction costs.

5. **Housing financing:** Housing investment requires a mortgage contract and is also subject to entry (transaction) costs. Mortgage loans are available from a financial sector that receives deposits from households and also loans funds to private firms. In this article, we stress the importance of financial innovation in the mortgage market through the introduction of new mortgage products. We represent the type of mortgage product held by a household by $z \in \mathcal{Z} = \{0, 1, \ldots, Z\}$, where $z = 0$ indicates that no mortgage is held. Mortgage contracts can differ along a number of dimensions such as downpayment, amortization terms, length of contract, and interest payment.

   The decision to purchase a house of size h' at price p requires a downpayment equal to $\chi(z) \in [0, 1]$ percent of the value of the house. The downpayment requirement depends on mortgage type, z. The initial amount borrowed is represented by $D(N) = (1 - \chi\ (z))ph'$, where N is the length of the mortgage contract. In each period, n, a household with

intensely to utilize the house, but does not consider the associated costs if she is not the owner of the house. This assumes the mortgage contract cannot be written to explicitly provide for such contingencies. In order to have housing services rented by nonhomeowners, the renter must pay higher contract rents.

[13] Household preferences, financial incentives, or the allocation of control have also been used as arguments to explain why renting is more expensive than owning.

mortgage type z faces a mortgage payment that depends on the price of housing p, the housing size h', the length of mortgage N, the downpayment fraction $\chi(z)$, and the mortgage interest rate r^m (z). A mortgage payment in period $n \in \mathcal{N} = (0, 1, \ldots, N)$ can be represented as $m(x, z)$, where x defines the set $(p, h', \psi$ $(z), n, N, r^m$ $(z))$.[14]

For any mortgage contract, payment can be decomposed into an amortization term, $A(n, z)$, that depends on the amortization schedule, and an interest rate payment term $I(n, z)$, which depends on the payment schedule. That is,

$$m(x, z) = A(n, z) + I(n, z), \tag{1}$$

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

$$D(n-1, z) = D(n, z) - A(n, z), \tag{2}$$

or combining this expression with the mortgage payment $m(x, z)$ yields

$$D(n-1, z) = (1 + r^m(z))D(n, z) - m(x, z). \tag{3}$$

The law of motion for home equity increases with mortgage payments. That is,

$$E(n-1, z) = E(n, z) + [m(x, z) - r^m(z)D(n, z)], \tag{4}$$

where $E(N, z) = \chi(z)ph'$ denotes the home equity in the initial period.

In the baseline model, we assume that the only contract available is a standard FRM, $z = 1$. This mortgage contract is characterized by a constant mortgage payment over the length of the mortgage, which results in an increasing amortization schedule of the principal and a decreasing schedule for interest payments. That is, the constant payment schedule satisfies $m(x, z) = \lambda D(n, z)$, where $\lambda = r^m(z)[1 - (1 + r^m$ $(z))^{-N}$ $]^{-1}$. 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 of the mortgage contract. That includes the mortgage payment, liabilities with the financial intermediary, and equity in the house.

6. **Tax treatment of housing:** The tax treatment of housing differs from capital investment. The model captures some of the prominent provisions in the tax code towards housing. Those include a distortionary tax code, the

[14] In this article, we assume mortgages have the same contract length. In addition, a mortgage payment is made in the period the mortgage is written. This is due to the fact that in our model a household is able to purchase a home and consume the service flow from that house in the same period.

deductibility of mortgage interest payments, $I(n, z)$, and the exclusion of the imputed rental value of owner-occupied housing from taxable income, Rs.[15] The tax code favors housing investment relative to real capital and owner-occupied housing to rental housing.

3.2. *Households.* Households are described by preferences, earnings capabilities, and age. We index a household's age by $j \in \mathcal{J} = \{1, 2, \ldots, J\}$, where each household lives to a maximum of J. Survival each period is uncertain. The conditional probability of surviving from age j to age $j+1$ is represented by $\psi_{j+1} \in [0, 1]$, where $\psi_1 = 1$. Life expectancy for a newborn cohort is given by $\prod_{j=1}^{J} \psi_{j+1}$. Household preferences are represented by index function $u(c, s)$, where c is the consumption of goods and s represents the amount of housing services consumed. The utility function $u: R^2 \to R$ is C^2 and satisfies the standard Inada conditions. Lifetime utility is discounted every period at a rate $\beta > 0$.

Households are endowed with a fixed amount of time each period and they supply this endowment to the labor market inelastically until retirement at age $j^* < J$. Households differ in their productivity for two reasons—age- and period-specific productivity shocks. We define υ_j as the average labor productivity of an age j individual. A household also draws a period-specific earnings component, ϵ, from a probability space, where $\epsilon \in \mathcal{E}$. The realization of the current period productivity component evolves according to the transition law $\Pi_{\epsilon,\epsilon'}$. Thus, a worker's gross labor earnings in a given period are $w\epsilon\upsilon_j$, where w is the market wage rate. Additional sources of income are interest earnings, ra, and rental income received by supplying housing services to the rental market $R(h' - s)$, where R represents the rental price. Rental income can only be received by those households that have a housing investment position $h' > 0$ and pay a fixed cost to supply rental property. Retired households receive a social security benefit from the government equal to θ. We define the household's gross income as

$$(5) \qquad gy(a, h', s, \epsilon, \upsilon_j, j; q) = \begin{cases} w\epsilon\upsilon_j + ra + R(h' - s), & \text{if } j < j^*, \\ \theta + ra, + R(h' - s), & \text{if } j \geq j^*, \end{cases}$$

where $q = \{p, R, r, r^m\}$ represents a price vector. The U.S. tax code treats the imputed income from housing services differently depending on who consumes the services from housing. In this formulation, we capture the asymmetric treatment of housing where rental income is taxable, $R(h' - s)$, but the imputed services flows from owner-occupied housing, Rs, are not taxable. All other sources of income (labor, savings, and social security payments) are subject to taxation. The tax code differentiates exemptions from deductions. We define adjusted income as gross

[15] In the U.S. tax code, capital gains from owner-occupied housing are usually tax exempt, whereas those from rental property are taxed. In our model, we do not make a distinction between owner- and rental-occupied housing investment; as a result we assume that capital gains are not taxed. This assumption does not affect the nature of our main results with respect to ownership and is made for tractability.

income minus deductions Γ. Formally,

$$ay(a, h', s, \epsilon, j; q) = gy(a, h', s, \epsilon, j; q) - \Gamma.$$

Examples of such deductions could be a deduction for mortgage interest rate payments or maintenance expense deductions.

In this economy, the government uses a progressive income tax represented by the function $T(ay)$, where ay denotes adjusted gross income. The tax function is continuously differential, where $T'(ay) > 0$ represent the marginal tax rate and $T(ay)/ay > 0$ represents the average tax rate. In addition, labor earnings are subject to social security contributions denoted by τ_p. We define after-tax income as

$$(6) \quad y(a, h', s, \epsilon, \upsilon_j, j; q) = \begin{cases} (1 - \tau_p)w\epsilon\upsilon_j + (1 + r)a - T(ay), & \text{if } j < j^*, \\ \theta + (1 + r)a - T(ay), & \text{if } j \geq j^*. \end{cases}$$

The household's current period budget constraint depends on the household's exogenous income shock, ϵ, its beginning of period asset holding position, a, the current housing position, h, mortgage choice, z, the length of the mortgage contract remaining, n, the current age, j, and the household decisions with respect to their consumption, c, housing consumption, s, asset position, a', and housing position, h', for the start of the next period. We can isolate five different situations with respect to the household problem.

1. **Renter**
   In this model there are two ways for a household to consume rental-occupied housing in the current period. A household could have been a renter in the prior period and choose to remain a renter. Alternatively, a household could have been a homeowner in the prior period and decide to sell the housing property and become a renter in the current period. The choice problem depends on the housing investment decision.
   Renter yesterday ($h = 0$) and renter today ($h' = 0$): Consider a household that does not own a house at the start of the period, $h = 0$, and decides to continue renting housing services in the current period, $h' = 0$. This individual does not have a mortgage contract in either period $z = z' = 0$ and thus has no mortgage payment obligations, so $n = n' = 0$. The decision problem in recursive form can be expressed as

$$v(a, 0, 0, 0, \epsilon, j) = \max_{(c,s,a')} \left\{ u(c, s) + \beta\psi_{j+1} \sum_{\epsilon' \in \mathcal{E}} \pi(\epsilon, \epsilon')v(a', 0, 0, 0, \epsilon', j + 1) \right\},$$

$$(7) \qquad \text{s.t.} \quad c + a' + Rs = y(a, h', s, \epsilon, \upsilon_j, j; q) + tr,$$
$$c, s, a' \geq 0,$$

where Rs denotes the cost of the housing services purchased in the rental market and tr is the lump-sum transfer from accidental bequests. The constraint $a' \geq 0$ indicates that asset markets are incomplete as short-selling is precluded.

Homeowner yesterday ($h > 0$) and renter today ($h' = 0$): In this case, the household enters the period with a positive housing investment position, $h > 0$, and decides to rent, $h' = 0$, in the current period.[16] The decision to sell property is subject to an idiosyncratic capital gain shock, ξ, that determines the final sale value, $p\xi h$, that the homeowner receives when changing the size of the housing investment. The unconditional probability of the shock is π_ξ. The optimization problem for this situation is

$$v(a, h, z, n, \epsilon, j) = \max_{(c_\xi, s_\xi, a'_\xi)} \left\{ \sum_{\xi \in \Xi} \pi_\xi \left[u(c_\xi, s_\xi) + \beta \psi_{j+1} \sum_{\epsilon' \in \mathcal{E}} \pi(\epsilon, \epsilon') v(a'_\xi, 0, 0, 0, \epsilon', j+1) \right] \right\},$$

$$\text{s.t. } c_\xi + a'_\xi + Rs_\xi = y(a, h', s, \epsilon, \upsilon_j, j; q) + tr + [(1 - \phi_s)p\xi h - D(n, z)], \quad (8)$$
$$c_\xi, s_\xi, a'_\xi \geq 0.$$

In this specific case, the sale of the house generates income, $p\xi h$, net of selling costs, ϕ_s and the remaining principal $D(n, z)$, which depends on the mortgage type z.[17] For households with no mortgage, $D(0, 0) = 0$. Notice that the consumption of goods, housing services, and savings are conditioned on the idiosyncratic capital gain shock. This is because net income depends on the realization of ξ.

2. **Homeowner**

In the model, there are three different avenues for a household to have a housing investment position, $h' > 0$, in the current period. A household could have been a renter in the prior period and decide to purchase a home. Alternatively, a household could have been a homeowner in the prior period. In the current period, the household can remain a homeowner by maintaining the same housing investment position, or either upsize or downsize housing investment. Each choice involves different constraints.

Renter yesterday ($h = 0$) and become a homeowner ($h' > 0$): In this case, we have a household who rented in the previous period, $h = 0$, and chooses to invest in housing, $h' > 0$. The housing investment is financed

[16] 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, $h' = a' = 0$.

[17] As our analysis will be 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, p, except for the idiosyncratic capital gain shock.

by a mortgage contract choice, z, which requires an initial expenditure of $(\phi_b + \chi(z))ph'$, where ϕ_b is a transaction cost parameter and $\chi(z)$ represents the downpayment requirement of the contract. The period mortgage payment is $m(x, z)$. In this model we separate housing investment from housing consumption. The reason for the distinction is that households have the ability to sell housing services, thus generating rental income. To participate in the rental market as a landlord, a period fixed cost, $\varpi > 0$, must be incurred.[18] Otherwise, the optimal housing consumption is determined by 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,

$$v(a, 0, 0, 0, \epsilon, j) = \max_{\substack{(c,s,a',h') \\ z' \in \mathcal{Z}, I_r \in \{0,1\}}} \left\{ u(c, s) + \beta \psi_{j+1} \sum_{\epsilon' \in \mathcal{E}} \pi(\epsilon, \epsilon') \times v(a', h', z', \max(n-1, 0), \epsilon', j+1) \right\},$$

$$\text{s.t.} \quad c + a' + (\phi_b + \chi(z))ph' + m(x, z) + x(h', s) = y(a, h', s, \epsilon, v_j, j; q) + tr + I_r [R(g(h') - s) - \varpi], \tag{9}$$

$$c, s, a', h' \geq 0 \text{ and } s \leq g(h').$$

The actual maintenance expense, $x(h', s)$, depends on whether some of the housing services are rented to other individuals. In addition, the choice of mortgage product is defined over a discrete number of choices where the *max* operator is defined over the optimal choice z^*. In the baseline model we restrict the set of choices to $z \in \mathcal{Z} = \{0, 1\}$, and hence, all homeowners choose $z' = 1$.

Homeowner maintains housing size ($h = h' > 0$): In this case the household maintains the same housing investment, $h = h'$, and mortgage contract, $z = z'$.[19] We allow for the possibility that the homeowner has paid off her mortgage so that $z = 0$ and $n = 0$. The optimization problem can

[18] In this economy, 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 us to formalize the rental market, keeping the state space relatively tractable. Introducing two different housing stocks such as owner-occupied and rental-occupied would require solving a larger portfolio choice problem with additional computational complexity.

As a result, all the landlords are homeowners but not the other way around. The AHS reports that the fraction of individuals that report receiving rental income as well as consuming rental housing services is almost zero.

[19] The objective of the article was to understand changes in the aggregate homeownership rate, not to explain the observed refinancing.

be described as

$$v(a, h, z, n, \epsilon, j) = \max_{\substack{(c,s,a',h') \\ I_r \in \{0,1\}}} \left\{ u(c, s) + \beta\psi_{j+1} \sum_{\epsilon' \in \mathcal{E}} \pi(\epsilon, \epsilon') \times v(a', h', z', \max(n-1, 0), \epsilon', j+1) \right\},$$

$$\text{(10)} \quad \text{s.t.} \quad c + a' + m(x, z) + x(h', s) = y(a, h', s, \epsilon, \upsilon_j, j; q) + tr + I_r \left[R(g(h') - s) - \varpi \right], \quad c, s, a', h' \geq 0 \text{ and } s \leq g(h'),$$

where $n' = \max\{N - 1, 0\}$. In this situation, the household must make a mortgage payment if $n > 0$. Again, it is important to remark that the decision to consume housing services and the size of maintenance expenses depends on choice of paying a fixed cost ϖ to become a landlord.

Homeowner changes housing size ($h \neq h' > 0$): The household decides to either upsize ($h' > h > 0$) or downsize ($h > h' > 0$) its housing investment. The optimization problem is more cumbersome since we have to jointly determine the mortgage choice and the housing service consumption decisions, as well as account for the uncertainty associated with selling the prior housing position, h. The recursive problem is

$$v(a, h, z, n, \epsilon, j) = \max_{\substack{(c_\xi, s_\xi, a'_\xi) \\ z' \in \mathcal{Z},\ I_r \in \{0,1\}}} \left\{ \sum_{\xi \in \Xi} \pi_\xi \left[u(c_\xi, s_\xi) + \beta\psi_{j+1} \sum_{\epsilon' \in \mathcal{E}} \pi(\epsilon, \epsilon') \times v(a'_\xi, h'_\xi, z', N-1, \epsilon', j+1) \right] \right\},$$

$$\text{(11)} \quad \text{s.t.} \quad c_\xi + a'_\xi + (\phi_b + \chi(z')) p h'_\xi + m(x, z') + x(h', s) = y(a, h', s, \epsilon, \upsilon_j, j; q) + tr + I_s \left[R(g(h'_\xi) - s_\xi) \right] + [(1 - \phi_s) p \xi h - D(n, z)], \quad c_\xi, s_\xi, a'_\xi, h'_\xi \geq 0 \text{ and } s_\xi \leq g(h'_\xi).$$

This constraint accounts for the additional income from selling their home (net of transaction costs, $\phi_s p \xi h$, and remaining principal, $D(n, z)$), the cost of buying a new home, as well as the capital gain shock associated with the sale of the home. Once again individual choices depend on the realization of the idiosyncratic shock ξ. In this case, both the savings and housing investment choices depend on the amenity shock.

3.3. *Financial Sector.* The financial intermediary is a zero-profit firm. This firm receives the deposits of the households, a', and offers mortgages to the household sector as well as loans to production firms. These mortgages generate revenues each period. In addition, financial intermediaries receive principal payments from those individuals who sell their home or unexpectedly die with an outstanding mortgage position. These payments are used to pay a net interest rate on these deposits, r. The balance sheet of the financial intermediary is represented by

Financial Intermediary Balance Sheet

Assets	**Liabilities**
Loans to firms	Deposits
Net mortgage loans	

We postpone the description of the market-clearing condition for the financial sector until the description of market equilibrium.

3.4. *The Production Sector.* A good, which can be used for consumption, capital, or housing purposes, is produced by a representative firm that attempts to maximize profits. The production technology in this sector is given by a constant return to scale technology $Y = F(K, L)$, where K and L are aggregate inputs of capital and labor, respectively. Capital depreciates at the rate δ each period. In the absence of adjustment costs in the housing stock, the relative price of capital and housing is unity.

3.5. *Government.* In this economy, the government engages in a number of activities ranging from financing exogenous government expenditure, providing retirement benefits through a social security program, to redistributing the wealth of those individuals who die unexpectedly. We assume that the financing of government expenditure and social security are run under different budgets.

The government provides retirement benefits, θ. These benefits are financed by taxing employed individuals at the tax rate τ_p. Since this policy is self-financing, the tax rate depends on the retirement benefit or replacement ratio. This relationship can be written as

$$\tau_p = \frac{\theta \left[\sum_{j=1}^{j^*-1} \sum_i (\mu_j w v_j \epsilon_i) \Big/ \sum_{j=j^*}^{J} \mu_j \right]}{\sum_{j=1}^{j^*-1} \sum_i (\mu_j w v_j \epsilon_i)}, \tag{12}$$

where μ_j is the size of the age j cohorts.

In the general budget constraint, government expenditures are determined by the amount of revenue collected from income taxation. Since income taxes are not linear we define $t(a, h, z, n, \epsilon, j)$ to be the tax obligations of each household based in its position in the state space. Hence, the general budget constraint can be expressed as

$$G = \int \mu_j t(a, h, z, n, \epsilon, j)\Phi(da \times dh \times dz \times dn \times d\epsilon \times dj). \tag{13}$$

The term $\Phi(\cdot)$ represents the measure of households.

Finally, the government collects the physical and housing assets of those individuals 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

$$tr = \frac{Tr}{1 - \mu_1},$$

where *Tr* is the aggregate (net) value of assets accumulated over the state space from unexpected death and is defined as[20]

$$\begin{aligned} Tr = &\int \mu_j(1 - \psi_j)a(a, h, z, n, \epsilon, j)\Phi(da \times dh \times dz \times dn \times d\epsilon \times \{2, .., J\}) \\ &+ \sum_{\xi \in \Xi} \pi_\xi \int \mu_j(1 - \psi_j)[(1 - \phi_s)p\xi h(a, h, z, n, \epsilon, j) - D(a, h, z, n, \epsilon, j)] \\ &\times \Phi(da \times dh \times dz \times dn \times d\epsilon \times \{2, .., J\}). \end{aligned}$$

3.6. *Market Equilibrium Conditions.* This economy has four markets: the asset market, labor market, the rental of housing services market, and the goods market. All these markets are assumed to be competitive.

In this model, the asset market-clearing condition is complicated by the presence of mortgages and unexpected death. In attempt to clarify, we introduce some additional notation that distinguishes whether a decision is impacted by an idiosyncratic capital shock, which is realized only when a property is sold. The individual state vector can be summarized by $\Lambda = (a, h, z, n, \epsilon, j)$. Let $I_s(a, h, z, n, \epsilon, j) \equiv I_s(\Lambda)$ be an indicator value that is equal to 1 when housing is sold and zero

[20] In the formulation, the newborn generation does receive a lump-sum transfer, as we endow these individuals with capital assets as observed in data. In this model, the aggregate mass of households of age 1 year is μ_1 and total population is normalized to one.

otherwise. The total amount of capital available to firms, K', can be written as

$$
\begin{aligned}
(14)\quad K' = & \int_{I_s(\Lambda)=0} \mu_j a'(\Lambda)\Phi(d\Lambda) + \int_{I_s(\Lambda)=1} \sum_{\xi\in\Xi} \pi_\xi \mu_j a'_\xi(\Lambda)\Phi(d\Lambda) \\
& - \int_{I_s(\Lambda)=0} \mu_j(1-\chi(z))ph'(\Lambda)\Phi(d\Lambda) \\
& - \int_{I_s(\Lambda)=1} \sum_{\xi\in\Xi} \pi_\xi \mu_j(1-\chi(z))ph'_\xi(\Lambda)\Phi(d\Lambda) \\
& + \int_{I_s(\Lambda)=0} \mu_j m(x,z)\Phi(d\Lambda) + \int_{I_s(\Lambda)=1} \sum_{\xi\in\Xi} \pi_\xi \mu_j m(x,z)\Phi(d\Lambda) \\
& + \int_{I_s(\Lambda)=1} \mu_j D(\Lambda)\Phi(d\Lambda) + \int_{I_s(\Lambda)=1} \mu_j(1-\psi_j)D(\Lambda)\Phi(d\Lambda),
\end{aligned}
$$

where $\Phi(d\Lambda) \equiv \Phi(da \times dh \times dz \times dn \times d\epsilon \times dj)$.

The first two terms on the right-hand side of the equation capture the savings deposited by households to the financial intermediary. The former term captures savings if a property is not sold, whereas the latter term allows the savings decision to be impacted by the idiosyncratic capital gain shock when a home is sold and appropriately weighted by the measure of those households receiving a particular amenity shock. From this amount, new mortgages loans must be subtracted, and this is captured by the third and fourth terms on the right side. The two terms allow for differences created by the idiosyncratic capital gains shock. The next two terms account for mortgage payments received by the financial intermediary. That includes payments received by first-time buyers and existing homeowners who continue to make payments on their mortgage, as well as those homeowners that sell their property and have a new mortgage payment, which is affected by the idiosyncratic capital gain shock. The final terms on the right-hand side measure the payment of outstanding mortgage principal from those households who sell their house as well as the payment of outstanding debt of households who unexpectedly die with an outstanding principal.

The rental price of rental-occupied housing is determined by the aggregate amount of housing services made available by landlords and the total demand of rental housing services. That is, the rental market equilibrium condition is

$$
\begin{aligned}
(15)\quad & \int_{\substack{I_s(\Lambda)=0 \\ h'(\Lambda)>0}} \mu_j[h'(\Lambda)-s(\Lambda)]\Phi(d\Lambda) + \int_{\substack{I_s(\Lambda)=1 \\ h'(\Lambda)>0}} \sum_{\xi\in\Xi} \pi_\xi \mu_j[h'_\xi(\Lambda)-s_\xi(\Lambda)]\Phi(d\Lambda) \\
& = \int_{\substack{I_s(\Lambda)=0 \\ h'(\Lambda)=0}} \mu_j s(\Lambda)\Phi(d\Lambda) + \int_{\substack{I_s(a,h,z,n,\epsilon,j)=1 \\ h'(\Lambda)=0}} \sum_{\xi\in\Xi} \pi_\xi \mu_j s_\xi(\Lambda)\Phi(d\Lambda),
\end{aligned}
$$

where allowances for idiosyncratic gains shocks are incorporated.

The goods market-clearing condition is defined as

$$C + K' + I_H + G + \Upsilon = F(K, L) + (1 - \delta)K, \tag{16}$$

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. Aggregate consumption is defined as

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

The definition of aggregate housing investment is

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

Finally, Υ denotes total transaction costs and fixed costs, which is

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

The equilibrium wage is determined in a competitive labor market where labor demand is equal to labor supply. That is,

$$L^d = L^s \equiv \sum_{j=1}^{j^*-1} \mu_j v_j \epsilon, \tag{17}$$

where labor is inelastically supplied by households. Labor demand is determined by the firm's first-order condition.

3.7. *Stationary Equilibrium.* We restrict ourselves to stationary equilibria. The individual state of the economy is denoted by $(a, h, z, n, \epsilon, j) \in \mathcal{A} \times \mathcal{H} \times \mathcal{Z} \times \mathcal{M} \times \mathcal{E} \times \mathcal{J}$, where $\mathcal{A} \subset \mathbb{R}_+$, $\mathcal{H} \subset \mathbb{R}_+$, $z \subset I$, $\mathcal{M} \subset \mathbb{R}_+$, and $\mathcal{E} \subset \mathbb{R}_+$.

DEFINITION. A stationary competitive equilibrium is a collection of value functions $v(a, h, z, n, \epsilon, j,)$: $\mathcal{A} \times \mathcal{H} \times \mathcal{Z} \times \mathcal{M} \times \mathcal{E} \times \mathcal{J} \to \mathbb{R}$; decision rules $a'(a, h, z, n, \epsilon, j)$: $\mathcal{A} \times \mathcal{H} \times \mathcal{Z} \times \mathcal{M} \times \mathcal{E} \times \mathcal{J} \to \mathbb{R}_+$, and $h'(a, h, z, n, \epsilon, j) : \mathcal{A} \times \mathcal{H} \times \mathcal{Z} \times \mathcal{M} \times \mathcal{E} \times \mathcal{J} \to \mathbb{R}_+$; aggregate outcomes $\{K, N,\}$; prices $\{r, w, r^m, R\}$; government policy variables $\{\tau, \theta\}$; stationary population; and invariant distribution $\Gamma(a, h, z, n, \epsilon, j)$ such that

1. given prices $\{r, w, r^m, p, R\}$, the value function $v(a, h, z, n, \epsilon, j)$ and decision rules $c_\xi(a, h, z, n, \epsilon, j)$, $s_\xi(a, h, z, n, \epsilon, j)$, $a'_\xi(a, h, z, n, \epsilon, j)$, $I_{r\xi}(a, h, z, n, \epsilon, j)$ and $h'_\xi(a, h, z, n, \epsilon, j)$ solve the consumer's problem;[21]
2. given prices $\{r, w, r^m, p, R\}$, the aggregates $\{K, N\}$ solve the firms' profit maximization;
3. the price vector $\{r, w, r^m, R\}$ is consistent with the zero-profit condition of the financial intermediary;
4. the asset market as defined by Equation (14) clears;
5. the rental market as defined by Equation (15) clears;
6. the goods market as defined by Equation (16) clears;
7. the labor market as defined by Equation (17) clears;
8. the retirement program is self-financing as stated by Equation (12);
9. the government budget constraint expressed in Equation (13) holds;
10. let T be an operator that maps the set of distributions into itself; aggregation requires

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

 and T be consistent with individual decisions.

We will restrict ourselves to equilibria that satisfy $T(\Phi) = \Phi$.

4. PARAMETERIZATION OF MODEL

We parameterize the model to reproduce some key properties of the U.S. economy observed in 1994. We choose to estimate most of the parameters using an exactly identified Method of Moments approach. Once the economy is parameterized, we evaluate the model and then illustrate how the baseline model can be used to address the question posed with respect to homeownership. We commence by specifying the relevant functional forms and certain institutional parameters. We then discuss the choice of targets. It is important to remark on two aspects of the parameterization. First, the estimation procedure is embedded with the general solution of the model when equilibrium is computed. Second, the model is estimated to aggregate variables and not distributions.

[21] The subscript term ξ denotes that the decision rules are contingent on the value of the i.i.d. capital gain shock when a property is sold. If a sales does not take place, then this index would not appear.

4.1. *Preferences and Technology.* Our choice of the utility function departs from the standard constant relative risk aversion with a homothetic aggregator between consumption c and housing services s. This type of preference structure is not consistent with an increasing ratio of housing services/consumption ratio by age, which is observed in the data (see Jeske, 2005, for a detailed discussion). We assume that preferences over the consumption of goods and housing services can be represented by a period-utility function of the form

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

where $\sigma_1$and σ_2 determine the curvature of the utility function with respect to consumption and housing services. The relationship between σ_1 and σ_2 determines the growth rate of the housing to consumption ratio. When $\sigma_1 > \sigma_2$ the marginal utility of consumption exhibits relatively faster diminishing returns. In general, as income increases households choose to spend a larger fraction of income on housing.[22] We choose to set $\sigma_2 = 1$ and $\sigma_1 = 3$ to match the observed average growth rate, and the preference parameter γ is estimated.

Aggregate output is produced through a constant returns to scale Cobb–Douglas production function

$$F(K, L) = K^{\alpha} L^{1-\alpha},$$

where α represents the relative share of capital in output. The capital share parameter is 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.[23] In the absence of adjustment costs the price of housing is unity.

4.2. *Structural Parameters.*

- **Demographic structure:** We select a period in our model to be three years. An individual starts her life at age 20 years (model period 1) and lives till age 83 years (model period 23). Retirement is mandatory at age 65 years (model period 16). Individuals survive to the next period with probability ψ_{j+1}. These probabilities are set at survival rates observed in 1994, and data are from the National Center for Health Statistics, *United States Life Tables*, 1994. In a steady-state equilibrium with a stationary population, the size of each cohort is determined by μ_j. Each cohort share is determined from $\mu_j = \psi_j \mu_{j-1}/(1+\rho)$ for $j = 2, 3, \ldots, j$ and $\sum_{j=1}^{J} \mu_j = 1$, where ρ

[22] At some low income levels, expenditures of housing may not increase with increases in income. This is due to the existence of borrowing constraints and the "lumpiness" of the housing investment.

[23] We could have included this parameter as part of the estimation problem. We did not for two reasons. The value of this parameter is not controversial. In addition, expansion of the estimation problem will add computation time to a problem that takes significant time to compute.

denotes the rate of growth of population. Using resident population as the measure of the population, we set the annual growth rate to 1.2%.

- **Mortgage contracts and housing markets:** These parameters capture institutional features associated with mortgage contracts and housing markets. In the benchmark model, we assume that the only mortgage contract available is the standard FRM. The length of the mortgage, N, is set at 10, which corresponds to 30 years, and the downpayment requirement, $\chi(z)$, is set at 20%.[24] Buying and selling property is subject to transaction costs. We assume that all of these costs are paid by the buyer and set $\phi_s = 0$ and $\phi_b = 0.06$.

  The parameter ϖ affects the number of households that choose to become landlords. Determination of this parameter is difficult, as we have no direct evidence on the number of households that own rental property. An indirect measure is to calculate the number of households, or more precisely, the number of homeowners that report to receive rental income. In the AHS, around 10% of the sampled homeowners claim to receive rental income. With the lower bound estimate we choose to set ϖ to 0.05.
- **House size and capital gain shocks:** Given the lumpy nature of housing investment, the specification of the minimum house size, $\underline{h}$, has implications for the homeownership decision. If $\underline{h}$ is too large (small) the fraction of younger cohorts that will buy homes is small (large) and the model cannot replicate the observed aggregate homeownership. To avoid having the choice of this variable having inadvertent implications for the results, we determine the size of this grid point as part of the estimation problem. The remaining grid points are evenly spaced.

  We used data from the 1995 AHS to quantify the i.i.d. capital gain 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. We estimate a kernel density and then discretize the density into three even partitions. The average annualized price changes, ranging from lowest to highest, are -6.6, -1.4, and 10.5%. These values are adjusted to be consistent with a period being defined as three years. In order to test the robustness of these estimates, which are based on the individual household data from the AHS, we employed a similar approach using 1995 Tax Roll Data for Duval County in Florida which includes Jacksonville. These follow real estate properties as opposed to individuals. As a result, we can calculate annualized capital gains based in actual sales. We find very similar estimates for the idiosyncratic capital gain shock using this data source.

[24] The 1995 AHS is employed in the specification of these parameters. We construct a downpayment fraction using data on value of homes purchased and the amount borrowed on the first mortgage. A sample of 17,902 households is generated. The downpayment fraction for first-time home purchases is 0.1979, whereas the fraction for households that previously owned a home is 0.2462. We set χ corresponding to the first-time homeowner downpayment fraction. Since most households use a 30-year mortgage, we specify N to be equal to 10.

- **Endowments and labor income shocks:** Workers are assumed to have an inelastic labor supply, but the effective quality of their supplied labor depends on two components. One component is an age-specific, $\upsilon_{j,}$ 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 States, 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 et al. (2004). Based on their empirical work, we specify log (ϵ) to be

$$\log(\epsilon') = \omega' + \varepsilon',$$
$$\omega' = \Theta\omega + v',$$

where $\varepsilon\tilde{}N(0, \sigma_\varepsilon^2)$ is the transitory component and ω is the persistent component. The innovation term associated with this component is $v\tilde{}N(0, \sigma_v^2)$. They estimate $\Theta = 0.935$, $\sigma_\varepsilon^2 = 0.01$, and $\sigma_v^2 = 0.061$. 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 years. Each income state has assigned the corresponding level of assets to match the nonhousing wealth to earnings ratio.
- **Government and progressive income tax:** The government provides retirement income through a social security program. We assume the retirement program is self-financed through a payroll tax on the labor earnings of

workers. After retirement, households receive a transfer based on some fraction of the average labor income. We target the average replacement rate to 30%, which results in a worker payroll tax of 5.25%. Our inclusion of the government transfer program reduces the marginal utility of poor and retired households, thus minimizing possible distortions in the housing decisions of the elderly.

In addition to the retirement program, the government finances spending, G, through a progressive income tax. This choice captures some of the asymmetries in the U.S. tax code that favor owner-occupied housing. We allow mortgage interest payments and maintenance expenses for rental property to be deductible. Nevertheless, the imputed rental value of owner-occupied housing does not generate a tax obligation, whereas rental income is taxed. Following Conesa and Krueger (2006), we use the estimated functional form from Gouveia and Strauss (1994) to represent the income tax code. Total taxes $T(ay)$, based on adjusted gross income, are determined by the functional form

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

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

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

The parameter η_0 is a scaling factor and η_1 impacts the curvature of the tax function. The parameter η_2 determines the units used to measure income and the size of income deduction. Gouveia and Strauss estimate the policy parameters and find that $\eta_0 = 0.258$, $\eta_1 = 0.768$, and $\eta_2 = 0.0037$. In the benchmark economy we use the same parameter estimates employed by Gouveia and Strauss for η_1 but set η_2 to 0.371 to accommodate the model measurement units. The parameter η_0 is endogenously determined when solving the model to target the 7.4% ratio of federal government expenditure-GDP observed in 1994.[25] In all simulations, the parameters are set at the values estimated in the benchmark model and government expenditure is allowed to adjust. This choice is motivated by the fact that we are interested in the equilibrium effects associated with demographics changes and the introduction of new mortgage contracts. Adjusting the tax rate to generate the same level of revenues would obscure the direct impact of the aforementioned changes.

The entire set of parameters is presented in Table 3 in annualized terms.

The remaining structural parameters are estimated. The choice of estimation targets and the parameter estimates are discussed in the next section.

[25] The Gouveia and Strauss tax function was estimated for the period 1979–89. As our model is calibrated for the period 1994–96, 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.

TABLE 3
CALIBRATED PARAMETERS (ANNUAL VALUES)

Parameter	Value
Demographics	
J	83
J^*	65
ρ	0.012
Preferences	
σ_1	3.00
σ_2	1.00
Technology	
α	0.29
Housing	
χ	0.20
N	30
ϕ	0.06
ξ	[−0.066, −0.0148, 0.105]
Government	
η_1	0.768
η_2	0.371

4.3. *Estimation.* There are seven structural parameters that still need to be determined. We estimate these 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 individual discount rate, β, the minimum size of the smallest housing investment position, $\underline{h}$ and the tax function parameter, η_0. We define $\Theta = (\delta, \delta_r, \delta_o, \gamma, \beta, \underline{h}, \eta_0)$ as the vector of structural parameters. We identify these parameter values Θ so that the resulting aggregate statistics in the model economy $\bar{F}_n(\Theta)$ are determined by the seven specified targets $\bar{F}_n$ for $n = 1, \ldots, 7$ observed in the U.S. economy. The estimation of the structural parameters is not separated from the computation of market clearing. This means three additional equations (asset market, rental market, and accidental bequest) have to be satisfied. More details about the estimation are provided in the appendix.

Data for the seven targets are from two different sources: NIPA data and the AHS. We use the following targets based on NIPA data. The first 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 so as to be consistent with capital in the model. Output is GDP plus service flows from consumer durables less the service flow from housing.[26] The second target is the ratio of the housing capital stock to the nonhousing capital stock. The housing capital stock is defined as the value of fixed assets in owner and tenant residential

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

TABLE 4
ESTIMATION OF MODEL (ANNUAL VALUES)

Statistic	Target	Model	%Error
Ratio of wealth to gross domestic product (K/Y)	2.541	2.5446	0.143
Ratio of housing stock to fixed capital stock (H/K)	0.430	0.4266	−0.792
Housing investment to housing stock ratio (x_H/H)	0.040	0.0403	−0.388
Ratio housing services to consumption of goods (Rs_c/c)	0.230	0.2291	−0.411
Ratio fixed capital investment to GDP ($\delta K/Y$)	0.135	0.1353	0.339
Homeownership ratio	0.640	0.6370	−0.468
Government expenditure to output ($T(ay)/Y$)	0.074	0.0742	−0.005

Variable	Parameter	Value
Individual discount rate	β	0.9749
Share of consumption goods in the utility function	γ	0.9541
Tax function coefficient	η_0	0.1974
Depreciation rate of owner occupied housing	δ_o	0.0340
Depreciation rate of rental housing	δ_r	0.0749
Depreciation rate of capital stock	δ_k	0.0428
Minimum housing size	$\underline{h}$	1.4726

property. We find the ratio of the housing stock to nonhousing capital stock to be 0.43. The third target is the investment in capital goods to output ratio, which is 0.135. The ratio of the investment in residential structures to housing capital stock is the fourth target and is set at 0.121. The targeted housing consumption to nonhousing consumption is also based on NIPA data, where housing services are defined as personal consumption expenditure for housing and nonhousing consumption is defined as nondurable and services consumption expenditures net of housing expenditures. The targeted ratio for 1994 is 0.23, but the value does not vary greatly over the period 1990–2000. The final target using NIPA data is the government expenditure-output ratio. Defining government expenditure as federal government expenditures, we find this ratio for 1994 to be 7.4%. The remaining target is based on data from the AHS. The homeownership rate in the period 1994 is 64.2%.

The annualized values of the parameter estimates are summarized in Table 4.[27] The implied targets generated by the model solution along with the market-clearing equations are within less than 1% error in each target.

The baseline economy is estimated to match certain key features of the U.S. economy in 1994. We evaluate the performance of the model in terms of certain housing characteristics. A natural starting place is to inquire how the model performs in terms of certain aggregates. Since the aggregate homeownership rate is a target in the estimation problem, we examine whether the model generates a reasonable amount of young, or "first-time buyers." Data suggest that 37.3% of

[27] Our estimates of the depreciation rate on owner-occupied housing are somewhat higher than the estimates of Harding et al. (2007), who find the annual depreciation rate in the 2 to 2.5 range.

TABLE 5
SUMMARY OF AGGREGATE RESULTS

	Homeownership Rate (Over 25)	Homeownership Rate (Under 35)	Owner-Occupied House Size[1]	Fraction Landlord
Data 1994	64.0%	37.3%	2,137	10–15%
Baseline model 1994	63.7%	37.5%	2,348	17%

[1] Housing units are measured in terms of square feet.

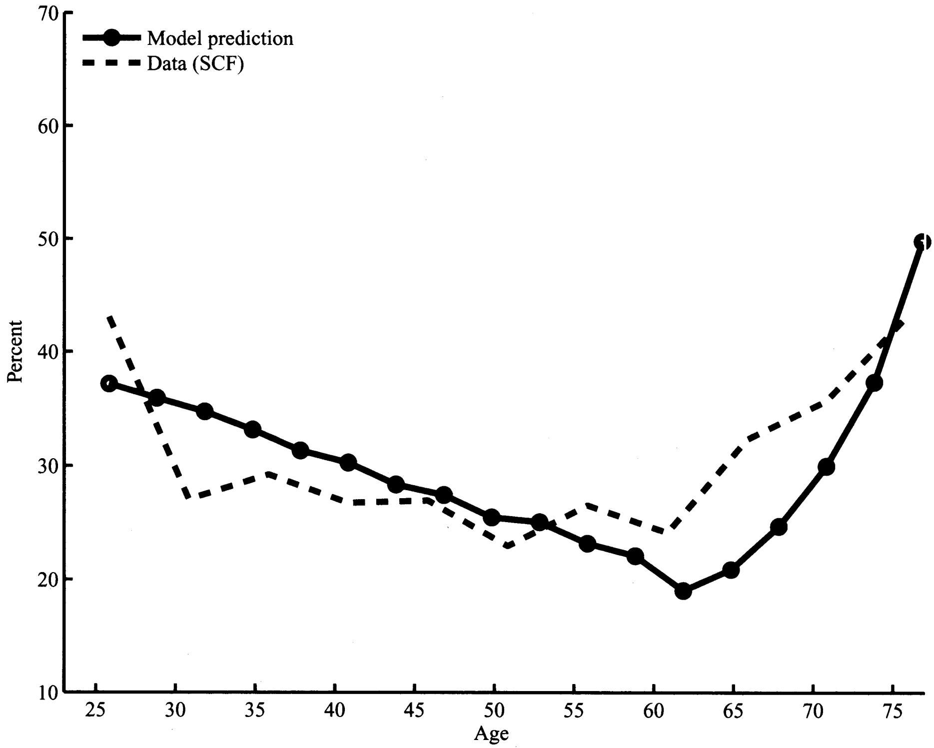
TABLE 6
HOMEOWNERSHIP RATES BY AGE AND INCOME

Variable by Age Cohorts	Homeownership Rate (%) 20–34	35–49	50–64	65–74	75–89
Data 1994	40.0	64.5	75.2	79.3	77.4
Baseline model 1994	37.5	76.5	86.4	91.3	66.5
By Income Group	1	2	3	4	5
Data 1994	46.6	56.1	64.4	75.5	89.1
Baseline model 1994	32.0	83.9	98.4	100.0	100.0

NOTES: Housing Vacancies and Homeownership (CPS/HVS) and AHS.

households under the age of 35 years own houses. The model generates a participation rate of 37.6%, indicating that the model slightly overstates homeownership for this cohort. Another dimension of interest is the consumption of housing services. We measure average consumption of housing services by average size of an owner-occupied house. Data from the AHS find the average owner-occupied house is 2,137 square feet. Our model implies an average house size of 2,348 square feet. Since the housing rental market is endogenously determined, we also examine this market. There are a number of ways to evaluate this aspect of the model. We calculate the fraction of households that choose to have a landlord position. Data from the AHS imply that between 10 and 15% of households have a rental position. Our model predicts that 17% of households have a landlord position. In other words, the model overpredicts entry into the rental market, which suggests the fixed entry cost may be too low. These aggregate results are summarized in Table 5.

The distributional behavior of the model must also be evaluated over various housing dimensions. The model stresses the role of housing as an investment and consumption good. The performance of the model with respect to investment in housing can be evaluated in a number of ways. The homeownership rate can be examined from either an age or income perspective. As can be seen in Table 6, the homeownership rate has a humped-shaped behavior, with the highest rate occurring in the 65–74 years age cohort. In general, the model generates a similar pattern. The model generates homeownership for the 20–34 and 75 years and over age cohorts that is smaller than what is observed. The underprediction of the oldest



NOTE: Survey of Consumer Finances.

FIGURE 3

HOUSING IN THE PORTFOLIO BY AGE

cohort, which is much larger as compared to the under-35 years cohort, is a result of the assumption that households must rent in the final period. For the other cohorts, the model generated a participation rate that exceeds observed values. It is important to note that the model generates renter behavior in all age cohorts. This is important if changes in mortgage market conditions are to be properly evaluated. We also examine the participation rates from an income perspective. The range of income is segmented into quintiles with the first group representing the lowest 20% of income. Data indicate the participation rate increases with income, but the model generates a much steeper profile than what is observed in the data.

An alternative way to evaluate the model with respect to investment in housing is to examine the share of housing in homeowners' portfolios by age cohorts. Figure 3 presents data and model results on the relative importance of housing in the portfolio by age. Actual data are from the 1994 *Survey of Consumer Finances*. We focus only on households that own a home and use the respondents' estimated value of their house adjusted for remaining principal to calculate the net housing investment position. Since the only other asset in the model is capital, we combine

TABLE 7

OWNER-OCCUPIED HOUSING CONSUMPTION

	Sq. ft. Owners					
		By Age Cohorts				
Simulation	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 1994	2,348	2,147	2,297	2,429	2,514	2,362

NOTES: AHS.

data on bond and stock holding to approximate this asset.[28] We use this data to calculate the fraction of household's portfolio in housing and find a "U-shaped" pattern. Flavin and Yamashita (2002) find a similar pattern in their work on household portfolios. This pattern reflects the fact that young households have a biased portfolio towards housing. As the household ages, income increases and alternative savings forms become feasible. Later in life, housing becomes relatively more important as the equity stake in the home grows with age, whereas other assets begin to be used for consumption purposes. A similar pattern of behavior is generated by the model.

Housing consumption should also be examined. Average housing size of owner-occupied housing in terms of square feet can be assembled from the AHS. In Table 7, we report observed housing size by age cohorts. Housing size increases until the age of 65 years when some downsizing begins to appear. The model captures the magnitude and the hump-shaped behavior by age groups. However, some overprediction of housing size is observed.

An alternative approach to evaluating the model is to examine the ratio of housing consumption to nonhousing consumption over the life cycle. Jeske (2005) states that this ratio increases over the life cycle. When we calculate this profile from the model, we find a housing to nonhousing consumption ratio that increases over the life cycle. Since the model seems to be a viable instrument, we next consider the question of why the homeownership rate has increased in the second half of the 1990s.

5. WHAT ACCOUNTS FOR CHANGES IN HOMEOWNERSHIP?

We now employ the model to analyze the observed increase in the homeownership rate since 1994. Our strategy is to decompose variations in homeownership caused by changes in key factors—demographic and innovations in the mortgage markets. We measure the importance of each factor by calculating the implied long-run equilibrium in the model when one factor is changed at a time while holding the other factor constant. More precisely, we begin by analyzing the implication

[28] Bonds are defined as bond funds, cash in life insurance policies, and the value of investment and rights in trusts or estates, whereas stocks are defined as shares of stocks in publicly held corporations, mutual funds, or investments trusts including stocks in IRAs.

TABLE 8
COMPARISON OF DEMOGRAPHIC EFFECTS WITH 1994 AND 2005 POPULATION GROWTH RATES

	Homeownership Rate					
		By Age Cohorts				
Simulation	Total	20–34	35–49	50–64	65–74	75–89
Data 1994	64.0	37.3	64.6	77.6	80.3	73.5
Data 2005	69.0	43.0	68.7	79.4	82.7	78.4
Difference	5.0	5.7	4.1	1.8	2.4	4.9
Baseline model 1994	63.7	37.5	76.5	86.4	91.3	66.5
Baseline model 2005	64.7	37.9	76.8	86.8	91.6	65.9
Difference	1.0	0.4	0.3	0.4	0.3	−0.4

NOTES: Housing Vacancies and Homeownership (CPS/HVS).

of demographic changes holding the characteristics of the mortgage market constant. Then, we hold constant demographic factor but allow for the introduction of new mortgage products. The last step is to allow both factors to change so we can estimate the joint effect of demographics and mortgage innovation. At the end of the section, we address short-run effects.

5.1. *Demographics Factors.* The aging population in the United States along with lower fertility rates and longer life expectancy has changed the demographic structure of the economy. During the 1990s, the share of the population between age 35 and 54 years became the largest cohort group. In a relatively short time, the number of individuals older than age 55 years will be of similar size to this younger cohort. Since the participation rate in the owner-occupied housing market increases with age until age 75 years, the observed movements in homeownership could be entirely driven by changing demographic factors. The simulations from Section 2 suggest that the demographic effects are small when only demographic factors are allowed to change. However, this exercise does not take into consideration the impact of demographic factors for individual behavior and market prices. In this section, we use our quantitative model to examine the implications of changing demographics for the homeownership rate.

Table 8 summarizes the impact of a change in the demographic structure in the model by generating a long-run population distribution based on the observed population growth rate in 2005 rather than the growth rate observed in 1994. The baseline model generates a long-run aggregate homeownership rate of 63.7%. When the stationary population structure based on the 2005 growth rate is employed, the homeownership rate increases to 64.7%. The resulting increase of 1 basis point suggests that the impact of demographic factors is relatively small as the actual change in the homeownership rate is 5 basis points. In other words, the model indicates that changes in the population structure account for 20% of the long-run change in the homeownership rate.

The 1% increase in homeownership is distributed across all age groups until age 74 years. Those individuals of 75 years and over slightly reduce their participation.

The distributional impact is very small and is influenced by the general equilibrium effects that affect the rental price and the interest rate. The increase in the number of middle-aged and older households leads to an increase in savings and a small reduction in the interest rate. The increase in homeownership results in an increase in the supply of rental property, which reduces the rental rate. The oldest age group takes advantage of these equilibrium price effects by reducing homeownership and renting housing services. The primary problem with the demographic explanation is the failure to account for the observed individual cohort changes. The actual increase in the participation rate for households under age 35 years is not observed when only demographic factors are considered. Consequently, to understand the behavior of these younger cohorts we need to consider additional factors.

5.2. *Innovations in the Mortgage Market.* Since the early 1990s, a number of developments have occurred with respect to the financing of the housing investment. These changes include a reduction in the cost of providing mortgage services, the introduction and expansion of new mortgage products such as the combo loan or no-downpayment mortgage, an expansion of subprime lending, and the growth and development of secondary markets to accommodate these new mortgage products. Although these innovations should have minimal impact for existing homeowners, they do affect households not in the housing market—the so-called first-time buyers—who may not meet downpayment restrictions or do not satisfy credit requirements. The effect of these innovations could be large for households not in the housing market. A combo loan, which allows homes to be purchased with minimum or zero downpayment, is an attractive mortgage product for households excluded due to a high downpayment constraint. In this section, we employ the quantitative model to examine the importance of innovations in the mortgage market that modify existing frictions.[29]

5.2.1. *Reduction in transaction costs.* The FHA publishes a series measuring the costs of fees and charges associated with FHA loans. Since 1985, fees have declined from approximately 2% of the purchase price to less than 0.5% of the purchase price. In addition, a number of private programs, such as the Nehemiah Program, the AmeriDream Downpayment Assistance program, the HART Action Resource Trust, Consumer Debt Solutions, and Partners in Charity, have

[29] An obvious question is why lower mortgage interest rates are not the reason why homeownership rates increased. Lower mortgage rates allow homeowners to face smaller mortgage payments, thus making homeownership more potentially affordable. Lower mortgage rates do not necessarily result in more homeownership if these households are borrowing constrained because of the lack of the downpayment. Painter and Redfearn (2002) examine the role of interest rates in influencing long-run homeownership rates and find that interest rates play little direct role in changing homeownership rates. Furthermore, an examination of the data indicates that the aggregate homeownership rate has been relatively steady between 1965 and 1994 despite fluctuations in (real) mortgage rates.

An analysis of changing interest rates is not possible in the current form of our model. We could examine the impact of a decline in the wedge between the risk-free rate and the mortgage interest rate. The wedge approximates a spread between the (long-term) mortgage rate and a risk-free government bond. Using the 30-year FHA mortgage rate and the interest rate on a 1-year government bond (secondary market), we found no evidence that this spread changed since 1995.

TABLE 9
A REDUCTION IN TRANSACTION COSTS (1994 POPULATION GROWTH RATE)

	Homeownership Rate					
		By Age Cohorts				
Simulation	Total	20–34	35–49	50–64	65–74	75–89
Baseline model 1994	63.7	37.5	76.5	86.4	91.3	66.5
Reduction transaction costs ($\phi = 3\%$)	64.1	38.3	76.6	87.3	91.4	65.7

TABLE 10
DOWNPAYMENT FIRST-TIME BUYERS BY LOAN TYPE

	FHA Loan	Other Loans
1995	21.6%	29.8%
1999	13.8%	22.1%
2001	18.1%	24.5%
2003	16.3%	24.1%

NOTES: AHS.

developed over the past decade to reduce closing costs. In order to investigate the impact of the reduction in transaction costs, we reduce the buying cost parameter from 6 to 3% in our model.

In Table 9, we summarize some of the results from this experiment where demographics have been held at their 1994 stationary values. The reduction in transaction costs results in an increase in the aggregate homeownership rate from 63.7 to 64.1%. However, the increase is not close to the 69% homeownership rate observed in the 2005. The reason why a decline in transaction costs does not result in a large increase in homeownership can be seen by examining homeownership rates for the 20–34 years age cohort. The increase in the homeownership rate for this particular cohort does not respond as much as observed in actual data.

5.2.2. *A reduction in downpayment requirements.* We have previously mentioned the importance of reducing the downpayment requirement if the homeownership rate is to change significantly. In this section, we investigate whether a reduction in the downpayment requirement will result in an increase in homeownership. During the 1994 to 2005 period, a number of innovations occurred that allow households to purchase housing with lower downpayments. Changes in screening techniques occurred. In addition, new government programs allowed for reduced downpayments for low-income and first-time buying households.[30] In Table 10, we present data from various samples of the AHS that allow us to determine how average downpayment ratios have changed over time. Between

[30] The Clinton administration enacted policies through the FHA to have lower downpayment requirements with mortgage insured loans. The Bush administration developed the Zero-Downpayment Initiative for FHA to generate additional first-time home buyers. These programs, no doubt, had a positive impact on the homeownership rate, but it might be hard to merit their impact given their relatively small funding.

TABLE 11

REDUCTION IN THE DOWNPAYMENT REQUIREMENT (1994 POPULATION GROWTH RATE)

	Homeownership Rate					
		By Age Cohorts				
Simulation	Total	20–34	35–49	50–64	65–74	75–89
Baseline model 1994	63.7	37.5	76.5	86.4	91.3	66.5
Reduction downpayment ($\chi = 10\%$)	63.5	38.0	76.3	85.1	90.8	66.3

1995 and 2003, the average downpayment for FHA loans declined. The decline in downpayment fractions between 1995 and 1999 can be partially attributed to the introduction of mortgage insurance. All FHA loans require mortgage insurance if the LTV ratio exceeds 80%. Mortgage insurance essentially allows the homeowner to trade off the size of the downpayment for a higher monthly payment until the LTV rate declines to 80%. However, by 2001, the average downpayment for an FHA loan increased back to 18.1%, and then declined in 2003. The higher downpayment ratios in the 2000s as compared to 1999 do raise the question whether a decline in this ratio could be the primary factor that accounts for the increase in the homeownership.

We explore the importance of reducing the downpayment requirements by conducting an experiment where the downpayment ratio is reduced from 20 to 10%. In this experiment, we maintain the assumption that the demographic environment is characterized by the 1994 steady-state values. In addition, we do not allow for the existence of mortgage insurance. The former assumption will tend toward conservative estimates, whereas the latter assumption introduces a bias toward a reduction in this borrowing constraint having a larger impact. The results from this experiment are reported in Table 11.

The reduction of the downpayment requirement does increase the homeownership rate in the youngest cohorts from 37.5 to 38%. Surprisingly, the downpayment reduction reduces the aggregate homeownership rate from 63.7 to 63.5%.

This result is due to general equilibrium effects that result in a higher interest rate when *all* households are forced to use a FRM with a lower downpayment fraction. The resulting higher interest rate means some prior homeowners with a 20% downpayment requirement now find homeownership not the appropriate decision. These results indicate that the effect of a downpayment requirement reduction on the aggregate homeownership rate is more complicated, as some age cohort homeownership rates increase whereas others decline. This suggests mortgage choice is an important dimension.

5.2.3. *Introduction of new mortgage products: Combo loan.* During the time period where the homeownership increased, a number of new mortgage loan products were introduced in the mortgage market. These products are known generically as "combo loans" and lessened the downpayments requirement while allowing households to avoid mortgage insurance. The combo loans are differentiated by their downpayment requirements. An "80–20" combo loan corresponds to a loan with a traditional LTV ratio of 80% where a second loan is used to fund the 20% downpayment. Alternatively, the "80–15–5" mortgage loan requires a 5% downpayment along with the remaining 15% coming from a second loan. In general, the interest rate on the second loan has approximately a 2% rate premium above the interest rate on the primary mortgage loan. Government-Sponsored Enterprises initiated the use of this product in the late 1990s, and this mortgage product became popular in private mortgage markets between 2001 and 2002. The reason that the combo loan dominates a standard FRM loan with mortgage insurance is that the insurance premium is based on the full loan value, whereas in the combo loan it is only on the secondary loan. Tax considerations make the benefits from the combination loan products even greater due to the higher interest payments associated with this loan. In this section, we analyze the impact of the introduction of this mortgage contract for the homeownership rate. We know from the prior section that replacing one loan product with a loan product having a lower downpayment requirement may not result in a large increase in the homeownership rate. In this section, we introduce a combo loan product while maintaining a standard fixed rate contract. The expansion of the set of mortgage contracts available allows households who prefer a traditional mortgage product to maintain that choice while allowing households that were previously excluded by the high downpayment requirement to now enter homeownership using a product with a lower downpayment requirement.

We conduct a set of experiments that measure the impact of the introduction of alternative forms of combo loans in conjunction with the standard FRM contract. In the simulations, the set of mortgage choices must increase to accommodate the combo loan choice. Households decide on the preferred contract, z^*, based on a comparison of the current net benefits and continuation value associated with each contract. The combo loan payment structure differs from the standard FRM since two different loans must be repaid. The primary loan covers $(1 - \chi(z))$ of the value of the dwelling $D_1(N_1, z) = (1 - \chi(z))ph'$ and is of maturity N_1 with mortgage payments $m_1(x, z)$. The secondary loan either fully or partially covers the remaining value of the dwelling, $\chi(z)ph'$. That is, the loan is equal to $D_2(N_2, z) = \varkappa\chi(z)ph'$, where $\varkappa \in (0, 1]$ determines whether a downpayment is required. If $\varkappa < 1$, then a downpayment equal to $(1 - \varkappa)\chi(z)ph'$ is required. The interest rate on the second loan includes an interest premium ζ, (where $\zeta > 0$), so the interest rate is $r_2^m = r_1^m + \zeta$, with maturity $N_2 \leq N_1$ and mortgage payment $m_2(x, z)$. The payment structure can be expressed as

$$m(x, z) = \begin{cases} m_1(x, z) + m_2(x, z) & \text{when} \quad N_2 \leq n \leq N_1, \\ m_1(x, z) & \text{when} \quad n < N_2, \end{cases}$$

where the laws of motion for the principal and equity payment for each loan are computed as in the mortgage with constant repayment.

To study the impact of mortgage innovation we assume that households have the choice of financing their housing investment with a standard 30-year FRM with a 80% LTV ratio and a 20% downpayment requirement or a combo loan. We

TABLE 12

HOMEOWNERSHIP RATES WITH COMBO LOANS (1994 POPULATION GROWTH RATE)

	Homeownership Rate					
		By Age Cohorts				
Mortgage Contracts Available	Total	20–34	35–49	50–64	65–74	75–89
Data 1994	64.0	37.3	64.6	77.6	80.3	73.5
Data 2005	69.0	43.0	68.7	79.4	82.7	78.4
Baseline model 1994	63.7	37.5	76.5	86.4	91.3	66.5
FRM (20% down) and combo (10% down)	64.8	39.5	77.3	87.2	91.7	65.9
FRM (20% down) and combo (5% down)	65.5	40.0	79.5	87.2	92.2	65.5
FRM (20% down) and combo (0% down)	68.1	46.6	82.2	85.1	90.8	66.2

NOTES: Housing Vacancies and Homeownership (CPS/HVS).

evaluate a set of combo loans each having the primary loan with a 80% LTV but having different downpayment requirements as part of the second loan. For each of these alternative combo products, we assume both mortgage contracts have a 30-year duration, and the premium on the second mortgage is 2% annually. This spread is consistent with the spread observed in the market over this period. We also assume the demographic structure corresponds to the 1994 stationary population distribution. The various experiments are summarized in Table 12.

We will start by considering a combo loan that includes a 10% downpayment. With this option being available, the model generates an aggregate homeownership rate of 64.8%. Thus, the homeownership rate is 1.1 basis points higher than in the environment where only a conventional FRM exists. If the downpayment percentage in the combo loan falls to 5%, the aggregate homeownership rate increases to 65.5%. This is almost a 2 basis point increase over a single mortgage environment. The introduction of mortgage choice eliminates the negative effect on the aggregate homeownership rate observed in the simulation where the downpayment is reduced for all homeowners. More importantly, the availability of the combo loan option results in an increase in the participation of the cohorts under age 35 years. The data indicate that this rate increased by 5.7 basis points since 1994. The model predicts that the participation rate for these households increases 2 basis points when the downpayment constraint is 10% and 2.5 basis points with a 5% downpayment requirement.

In the early 2000s, a combo loan that allowed a household to invest in housing without having a downpayment became popular. With this type of combo loan, the household borrows the full amount of the house value using a primary loan with a 80% LTV ratio and a secondary mortgage to cover the remaining 20%. The introduction of this alternative mortgage contract option into our model results in the aggregate homeownership increasing to 68.1% in contrast to a participation rate of 63.7% when only a traditional mortgage is available. The effect of the introduction of this contract for homeownership in the youngest cohort is even more dramatic, as the homeownership rate increases to 46.6%. This percentage exceeds the homeownership rate actually observed for this cohort in 2005.

TABLE 13

DISTRIBUTION OF COMBO LOAN HOLDER BY AGE (1994 POPULATION GROWTH RATE)

	Combo Loan Holdings						
			By Age Cohorts				
Mortgage Contracts Available	Percent FRM	Percent Combo	20–34	35–49	50–64	65–74	75–89
Baseline model 1994	100	0	0	0	0	0	0
FRM and combo (10% down)	81.4	18.6	55.1	21.9	15.8	5.8	1.4
FRM and combo (5% down)	76.8	23.2	42.8	24.4	17.2	13.4	2.2
FRM and combo (0% down)	67.2	32.8	38.5	24.1	17.9	14.8	4.7

The introduction of the combo loan option allows younger (first-time) buyers who lack the 20% downpayment to enter the housing market with a smaller downpayment coupled with larger future payments. Those households who can meet the 20% requirement can still choose the standard loan with a lower mortgage payments. As can be seen in Table 13, the model predicts that 77% of the homeowners choose a conventional FRM, whereas 23% choose the combo loan with a 5% downpayment. The combo loan is especially attractive to younger households, as the model finds they hold 42% of this product. The introduction of a combo loan product increases the homeownership rate across all the age cohorts with the exception of the cohorts of age 75 years and older.

The model finds that individuals between age 20 and 34 years hold the largest share of combo loan holdings. As the downpayment requirement declines, the share of combo loans held by the youngest cohort decreases. Despite the decline in this share, the total number of outstanding combo loan holdings by this cohort increases by 49%. It is important to recognize that homeownership rates increase as the downpayment requirement associated with the combo product decreases. This means the youngest cohort's use of the combo loan causes the largest contribution to the increase in the aggregate homeownership rate. The model finds that 32.8% of household choose the "no-downpayment" combo option.

In order to stress the importance of mortgage product choice, we re-examine the impact on homeownership rates if mortgage product choice is restricted to combo loan products. We have shown that a downpayment reduction has an important quantitative effect when combined with mortgage products that allow a lower LTV ratio. When only a single combo loan product is available, our results are very similar to the results when the downpayment requirement is reduced in a standard FRM. The simulations presented in Table 14 show that in an economy with a only a combo loan that requires a 5% downpayment requirement or a no-downpayment loan, the homeownership rate in the aggregate and for households under age 35 years decreases. The explanation for this result relies on interest rate changes. In the stationary equilibrium with only a standard mortgage contract with a 20% downpayment, the interest rate is 5.43%. When we replace this contract with a 80–15–5 combo loan the equilibrium interest rate increases to 5.64% in the primary loan with a 7.64% rate for the secondary loan.

TABLE 14
HOMEOWNERSHIP RATES WITH COMBO LOANS (1994 POPULATION GROWTH RATE)

	Homeownership Rate					
		By Age Cohorts				
Mortgage Contract	Total	20–34	35–49	50–64	65–74	75–89
Baseline model 1994	63.7	37.5	76.5	86.4	91.3	66.5
Combo (5% down)	55.8	30.5	65.6	79.0	83.3	61.3
Combo (0% down)	54.9	29.9	64.3	78.2	82.6	60.9

Our quantitative model illustrates the importance of introducing mortgage contracts that trade off the downpayment requirements for larger mortgage payments to understand the observed change in the aggregate homeownership rate. Although such data on mortgage holdings by product type are not readily available on the national level, the AHS asks homeowners about the source of their downpayment.[31] An examination of the responses indicates that the fraction of first-time buyers under 35 years of age that purchase a house with no downpayment increased 16% over this period, whereas from an aggregate perspective the fraction of households who do not use a downpayment is essentially unchanged. Other relevant motives such as personal saving and gifts have declined in importance. Although these data are suggestive at best, the results are consistent with our finding that first-time buyers are the household types who find combo loans especially attractive. These individuals, who tend to be under the age of 35 years, would report no downpayment if surveyed by the AHS.

5.3. *Demographic Effects and Mortgage Innovation: The Decomposition.* In this section, we use our quantitative model to measure combined effects of demographic factors and financial innovations to account for the observed increase in the aggregate homeownership rate. We ignore innovations in the financial sector that result in a reduction in transaction costs. The reason is that our prior analysis suggested that changes in transaction costs have small effects on the aggregate homeownership rate. Ignoring this innovation will tend to view our measure of financial innovation as a conservative measure.

In Table 15, we report how the expansion of the set of mortgage choices due to the introduction of the combo loan product affects the aggregate homeownership rate under a stationary demographic structure with the 2005 population growth rate. We find that changing both factors substantially increases the aggregate homeownership rate. A combo loan that requires a 5% downpayment results in an aggregate homeownership rate of 67%. If a combo loan has no downpayment requirement, we now find that the homeownership rate increases to 70%.

[31] There is some detailed information about mortgage holdings. This information mainly separates mortgages by maturity (i.e., 15 or 30 years) and different types of contracts (i.e., FRM, ARM, or balloon), but does not differentiate mortgages by downpayment types.

TABLE 15
HOMEOWNERSHIP RATES WITH COMBO LOANS (2005 POPULATION GROWTH RATE)

	Homeownership Rate					
		By Age Cohorts				
Mortgage Contract	Total	20–34	35–49	50–64	65–74	75–89
Data 1994	64.0	37.3	64.6	77.6	80.3	73.5
Data 2005	69.0	43.0	68.7	79.4	82.7	78.4
Baseline model 1994	63.7	37.5	76.5	86.4	91.3	66.5
FRM (20% down) and combo (5% down)	67.0	41.8	79.8	87.4	91.8	64.2
FRM (20% down) and combo (0% down)	70.0	48.0	84.2	86.5	91.4	66.2

NOTES: Housing Vacancies and Homeownership (CPS/HVS).

TABLE 16
SUMMARY DECOMPOSITION ANALYSIS FOR THE HOMEOWNERSHIP RATE (2005 POPULATION GROWTH RATE)

	Combo (5% Down)		Combo (0% Down)	
	Change	% Change	Change	% Change
Actual change	5.0		5.0	
Total change (model)	3.2		6.3	
Pure demographic effect	1.0	31.3	1.0	15.8
Pure financial innovation effect	1.8	56.3	4.4	69.8
Joint effect	0.4	12.5	0.9	14.3

We observe the participation rates for cohorts under age 35 years are very similar to those observed in the data when combo loan choice is combined with the 2005 demographic structure. Interestingly, the combined effects also increase the ownership rate for the next cohort by a magnitude not found in prior experiments. These results suggest that the introduction of the combo loan impacts the younger cohorts.

We now proceed to the decomposition exercise so we can measure the magnitudes of the various factors and thus answer the question of what accounts for the increase in the homeownership rate. We report the decomposition for the two combo loans products. The decomposition exercise from a long-run perspective is reported in Table 16.

We start by examining a combo loan with a 5% downpayment requirement. We first calculate the total change in the homeownership rate when both mortgage contract innovation and demographic structure are allowed to change and compare these results to those of the baseline model. This generates an increase in the homeownership of 3.2 basis points. This change understates the observed change of 5 basis points. The pure demographic effect is measured by introducing the 2005 stationary demographics and not introducing a new mortgage instrument. As we discussed previously, a 1 point basis point increase occurs. This tells us that the pure demographic effect accounts for 31.25% of the model generated change in the homeownership rate. The pure financial effect can be measured by the change that occurs when an additional mortgage instrument is available and demographics held constant at their 1994 stationary values. These values are also reported in Table 12. As can be seen, the introduction of the combo loan product in this environment results in an increase in the aggregate homeownership rate of 1.8 basis points or 56.3% of the change in the aggregate participation rate. The remaining effect, or joint effect, is the result of having a larger fraction of the population in life-cycle stages that have higher participation rates, and the fact that new mortgage products make it possible for a larger number of households to purchase housing. This effect accounts for 12.5% of the total change.

If the 5% combo loan is replaced with a no downpayment mortgage contract the model generates a 6.3 basis point increase in the aggregate participation rate. The pure demographic effect accounts for 15.8% of the total change, whereas the financial innovation effect accounts for 69.8%. The remaining 14.3% is the joint effect. We view this decomposition as an upper bound estimate of the long-run quantitative effects implied from financial market innovations.

5.4. *Transitional Dynamics.* The decomposition analysis from the previous section suggests that financial innovation has a larger long-run impact in ownership than demographics. Since demographic effects are transitory, we could be underestimating the short-run importance of this factor. The effects associated with the introduction of new mortgage contracts should be persistent, but could also have an important shorter run impact. We explore the short-run implications of these two factors by examining the transitional dynamics.

We start at $t = 0$ where we consider an economy when the choice of the mortgage contract is restricted to the standard fixed mortgage contract with a 20% downpayment. Since the population structure in 1994 is not stationary, we solve the model with the observed cohorts shares for this year. The resulting equilibrium give us the initial asset holding distribution. At $t = 1$, we introduce an expanded set of mortgage choices by introducing a 80–20–0 combo loan (or a no-downpayment combo loan) and then generate the homeownership rate path. We assume that the introduction of a new mortgage contract has not been anticipated by households. Since the initial population structure is not stationary, we use actual population cohorts between 1994 and 2005 and then use the population shares that would be generated as the cohorts converge to the stationary population structure. This takes approximately 25 periods in the model. To separate the importance of mortgage innovation from demographic effects, we also solve the model without financial innovation. Figure 4 summarizes the path for the ownership rate.

The introduction of the combo loan has an immediate effect on the aggregate homeownership rate. Most of the initial increase is generated by the larger participation of the younger cohorts. As expected, the initial increase in the ownership rate is larger the lower the downpayment requirement of the combo loan. In the years that immediately follow, further increases in the aggregate homeownership rate are attributed to the demographic factors.

As the population structure converges to the stationary distribution, the share of younger cohorts increases relative to the older cohorts. Despite the introduction

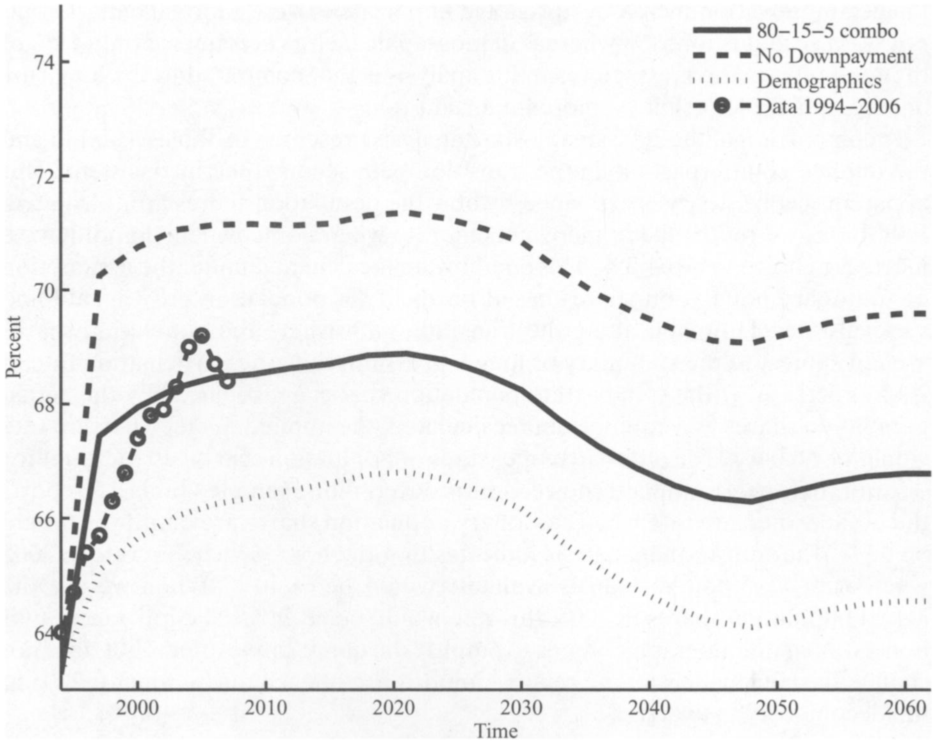


FIGURE 4

TRANSITIONAL DYNAMICS AND THE HOMEOWNERSHIP RATE

of new mortgage products, the participation rates of the younger cohorts are the smallest, and thus, the predicted aggregate homeownership rate falls. It is important to note that the long-run homeownership rate is higher than the rate in the initial period. As can be seen in Figure 4, the introduction of a new mortgage contract has lasting effects on the aggregate homeownership rate whereas demographic effects are transitory.

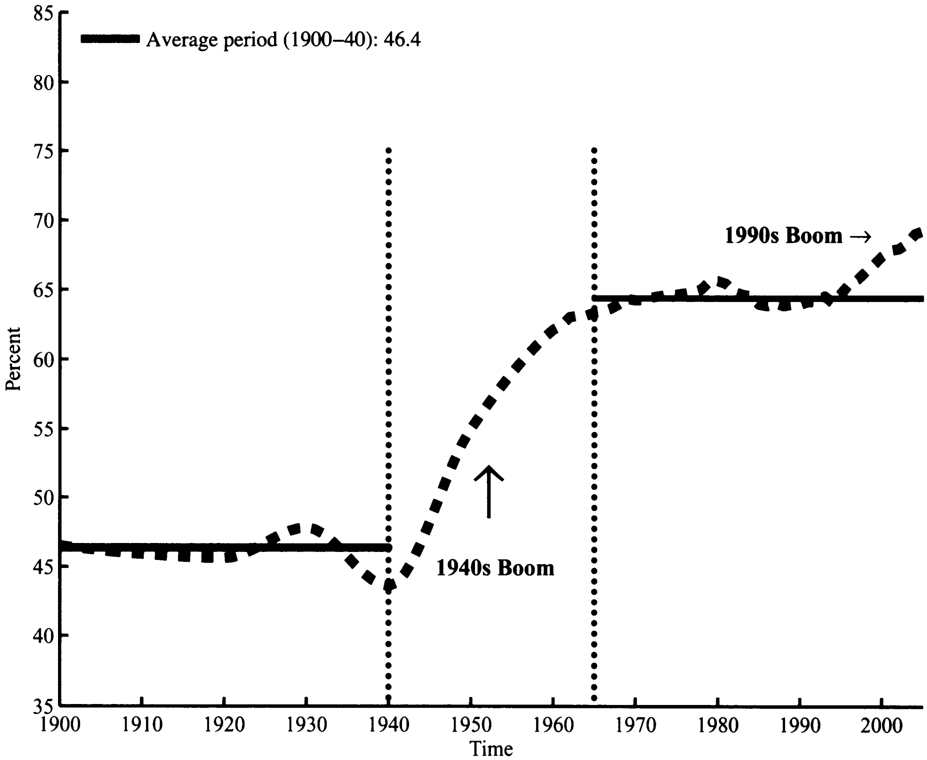
The transition path of homeownership allows us to determine whether the importance of the various factors differ from the long-run analysis. We focus on the year 2005 and examine the model predictions. In 2005, the actual homeownership rate was 68%. If only demographic factors are allowed to change, the homeownership rate would increase to 66.3%. This result indicates that the impact of demographic changes is larger in this year than in the long run. This is due to a relatively large fraction of households in the middle age cohorts where the participation rates are higher. If the combo loan requires a 5% downpayment, the homeownership rate would be 68.5%. In this case, demographic factors would account for 58% of the increase in homeownership and financial innovation the remainder. On the other hand, a zero-downpayment combo loan results in an even larger increase in the homeownership rate. In this case, the importance of financial innovation increases in relative importance. Now, mortgage market innovation accounts for 59% whereas demographic factors account for only 41% of the total effect. The message from this analysis is that compared to the long run, demographics factors play a more important role.

A comparison of the 2005 steady-state analysis presented in Tables 8 and 15 and the implied counterpart along the transition path seems to be inconsistent. This apparent inconsistency is explained by how the population shares are calculated. In Table 8, we report the homeownership rate when homeowners do not have a mortgage choice to be 64.7%. This equilibrium is calculated under the assumption of stationary population shares based on the 1994 population growth rate and survival rates. However, along the transition path where the population shares are not subject to the stationary or long-run assumption, the participation rate in 2005 is 66.25%. If the steady-state population shares are replaced by the actual population shares and equilibrium recalculated, the implied homeownership rate would be 66.04%. The alternative measures of population shares also account for differences when mortgage choice is introduced. For example, Table 15 reports the homeownership rate when stationary population shares are employed would be 67%. The transitional analysis indicates that the homeownership rate in 2005 when a 80–15–5 combo loan is available would be 68.40%. When we use the actual population shares in 2005, this rate would be 68.24%. The introduction of nonstationary demographics tends to amplify the quantitative effects but does not change the conclusions on the relative importance of each the factors for 2005 in the decomposition exercise.

6. POST–SECOND-WORLD-WAR HOUSING BOOM

The housing boom starting in the mid-1990s has a historical precedent. After World War II, the homeownership rate increased from 48% to roughly 64% over 20 years. This period was not only an important change in the trend, but determined a new level for the years to come. The expansion in homeownership during the postwar period has been part of the so-called "American Dream." The evolution of the aggregate homeownership rate between 1900 and 2005 is summarized in Figure 5.

The increase in the amount of owner-occupied housing had been a major federal policy goal since the collapse of mortgage markets during the Great Depression. In the late 1930s, the FHA played a role in altering the form and the terms of existing mortgage contracts. Prior to the Great Depression the typical mortgage contract had a maturity of less than 10 years, an LTV ratio of about 50%, and mortgage payments comprised only interest payments during the life of the contract with a "balloon payment" at expiration. The FHA sponsored a new mortgage contract characterized by a longer duration, lower downpayment requirements (i.e., higher LTV ratios), and self-amortizing with a mortgage payment that comprised both interest and principal. The aggregate impact of mortgage innovation during this time period has not been formally studied in a full-blown model. Rosen and Rosen (1980) study the determinants of tenure choice and the impact in homeownership during this time period. They use a time series model



NOTE: United States Statistical Abstract.

FIGURE 5

THE EVOLUTION OF THE HOMEOWNERSHIP RATE 1900–2005

where housing is restricted to be a consumption good, thus ignoring the investment aspect housing. They find that the introduction of tax provisions that favor owner-occupied housing (i.e., exclusion of imputed rents, the deductibility of property taxes, and mortgage interest payments) accounts for about 4 basis points of the total increase. Despite these effects, a large part of the total increase remains unaccounted.

We use our model to test the importance of the introduction of the standard FRM during that time period by running a counterfactual experiment. In this experiment, we employ all the parameters estimated in the benchmark economy for 1994. This year had about the same level of homeownership as observed during the mid-1960s. Then, we introduce the demographic structure from the 1940s and we restrict the set of mortgage choices to a 9-year balloon contract with a 50% downpayment. The objective of the experiment is not to capture the total magnitude observed during this time period, but rather to illustrate the importance of financial innovation in two periods where we have observed the largest

TABLE 17
HOMEOWNERSHIP AND THE 1940S

Simulation			
Contract Type	Population Structure	Ownership	Ownership ≤35
Data 1945		43.6	
12-year balloon (50% down)	1940 stationary	54.9	27.5
9-year balloon (50% down)	1940 stationary	54.9	27.3
9-year balloon (50% down)	1940 actual	54.4	27.3

NOTES: United States Statistical Abstract.

growth in aggregate homeownership.[32] The model predictions are summarized in Table 17.

The model predicts that the aggregate homeownership rate should fall from around 64% to less than 55%. Theses two combined effects predict close to 10 basis points of the total decrease. If we compare the magnitude of the introduction of the FRM with the combo loan we observe that the former had a very large impact on homeownership. The drop in the participation rate of the younger cohorts is equally dramatic. Even though the census data for homeownership rates by age are not readily available the model predicts a decline to 27.3%. This is over a 10 basis point drop for the younger cohorts. We view the importance of this counterfactual experiment as a clear illustration of the importance of innovations in the mortgage market, rather than a precise quantification of what actually happened during this earlier time period.

7. CONCLUSIONS

After three decades of being relatively constant, the homeownership rate steadily increased between 1994 and 2005. Movements in the homeownership rate in the United States are important, as stated policy is to have high homeownership rates. The objective of this article was to account for the observed increase in the homeownership rate and understand the role played by various factors such as demographics and innovations in the financial market where new loan products have been introduced. We construct a general equilibrium overlapping generations model with housing to measure the quantitative importance of these factors. The model features homeownership as part of the household's portfolio decision, the prominent role of life-cycle effects, the coexistence of rental- and owner-occupied, the choice of whether to own or rent, as well as the quantity of housing service flows to consume.

We find that the long-run importance of demographic effects for the aggregate homeownership rate is in the range of 16 to 31%. The effect of the introduction of new mortgage products ranges between 56 and 70%. The transitional analysis suggests that demographic factors play a more dominant role the further away

32 A complete analysis would require us to re-estimate the model to 1940s' aggregates, tax system, and determine the earnings process for the same time period.

TABLE 18
HOMEOWNERSHIP RATES ACROSS COUNTRIES

Rank Country	1996	2003	Difference
Spain	76	85.3	9.3
Greece	70	83.6	13.6
Italy	67	75.5	8.5
Belgium	65	72.9	7.9
Luxembourg	66	70.8	4.8
United Kingdom	67	70.6	3.6
Denmark	50	65.0	15.0
France	54	62.7	8.7
Sweden	43	59.9	16.9

NOTES: UNECE Environment and Human Settlements Division, Housing database.

from the long-run equilibrium. We show that the key to understanding the increase in the homeownership rate is the expansion of the set of mortgage contracts. The new loan products are known as the combo loan and are characterized by lower downpayment requirements. We find that combo loans tend to be the contract of choice for younger cohorts, which explains an important part of the increase in the aggregate homeownership rate observed since 1994. Demographic factors are especially important in understanding participation rate changes of households older than age 50 years.

The importance of financial market innovations in explaining increases in the homeownership rate can be further tested by considering developments in the housing market immediately after World War II. In the next two decades, the homeownership rate increased from 48% to roughly 64%. We perform a counterfactual experiment to measure the importance of the introduction by the FHA of the standard FRM contract to replace the existing balloon contracts that caused part of the collapse in the housing market during the Great Depression. Our quantitative model suggests that 50% of the increase in homeownership can be attributed to the introduction of the new mortgage product.

The recent boom in housing is not restricted to the Unites States. In Table 18, we report homeownership rates in 1996 and 2003 for nine Western European countries. As can be seen, large increases in homeownership have also occurred in these countries. In particular, Spain, Greece, Italy, France, and Sweden have increases exceeding 8 basis points. An obvious question is whether innovations in mortgage markets also account for the increase in participation rates in these countries. We leave this question for future research.

APPENDIX

Our computation strategy allows us to jointly solve for the equilibrium and the estimation process. To compute the equilibrium we discretize the state space by choosing a finite grid. However, choices for both types of consumption are continuous. The joint measure over the state space Λ (assets, a; housing, h; mortgage choice, z; periods remaining on the mortgage, n; income shock, ϵ; and age, j), is denoted by $\Phi(\Lambda)$ and can be represented as a finite-dimensional array. The estimation method is a mix between nonlinear least squares and an exactly identified generalized method of moments. The objective function to minimize can be written as the sum of two criteria:

$$L(\Theta) = \min_{\Theta}\{\lambda L_1(\Theta) + (1-\lambda)L_2(\Theta)\}.$$

The first criterion requires the estimate parameters to be consistent with market clearing in the asset market, market for rental-occupied housing, and lump-sum transfer from accidental bequest:

$$L_1(\Theta) = \sum_{i=1,2} \gamma_i \left(\frac{\bar{p}^i_{j+1}(\Theta_{j+1})}{\bar{p}^i_j(\Theta_j)} - 1\right)^2,$$

where $\bar{p}^i_{j+1}(\Theta_{j+1})$ represents the equilibrium price calculated with parameters Θ_{j+1} in iteration $j+1$. The second criterion requires the implied aggregates in the model $\bar{F}_n(\Theta)$ to match their counterpart in the data $\bar{F}_n$:

$$L_2(\Theta) = \sum_N \alpha_n(\bar{F}_n - \bar{F}_n(\Theta))^2.$$

The indirect inference procedure proceeds as follows:

- Guess a vector of parameters $\Theta \equiv (\beta, \gamma, \eta_0, \delta_o, \delta_r, \delta_k, \underline{h})$ and a vector of equilibrium objects $\bar{p} = (r, R, tr)$.
- Calculate the social security transfers from the invariant age distribution.
- Solve the household's problem to obtain the value function and decision rules.
- Given the policy functions, calculate the implied invariant distribution $\Phi(\Lambda)$, the implied aggregates $\{\bar{F}_n\}_{n=1}^N$, and equilibrium objects $\bar{p}$.
- Calculate $L(\Theta)$, and find the estimator of $\widehat{\Theta}$ that solves

$$\min_{\Theta} L(\Theta).$$

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