Tax Preferences and Housing Affordability: Explorations using a Life-Cycle Model*

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December 11, 2025

Abstract

We present a dynamic life-cycle model of demand for owner-occupied housing, investment property and liquid assets. Households face transaction costs, downpayment requirements, liquidity constraints, and tax preferences for owner-occupied housing. The model replicates key facts about home ownership, liquid assets, debt and consumption. Our model predicts eliminating the mortgage interest deduction (MID) and using the proceeds to cut income tax rates would increase ex ante welfare of all agents. We also predict that replacing MID with a refundable flat-rate mortgage interest credit would increase the ownership rate significantly while also improving welfare. Gains are concentrated among low to middle income households and young households, as housing becomes more affordable for them.

JEL classification: H20, H31, R21, G11, G51

Keywords: Housing demand, Mortgage interest, Imputed rent, Life cycle model

1 Introduction

Home ownership in the US receives three important tax advantages: Home mortgage interest is tax deductible, the implicit rental income on owner-occupied housing is not taxed, and capital gains on owner-occupied home sales are largely untaxed. These tax preferences have been justified on the grounds that home ownership may generate positive externalities (but that is subject to debate). Furthermore, there is a long-standing debate about the effects of subsidies on home ownership, see Rosen (1985); Poterba (1984, 1990, 1992). In particular, once one factors in the impact of these subsidies on income taxes, which must rise to pay for them, it is not clear that they make housing more affordable.

To analyze the impact of these tax advantages, we develop the first life-cycle model of demand for housing in which owner-occupied housing, investment property and financial

*Keane: Carey Business School, Johns Hopkins University, Cepar, UNSW; Liu: Hunan University. This research was supported by Australian Research Council grants FL110100247 and DP210103319, the ARC Centre of Excellence in Population Ageing Research (CE110001029), and the Young Scientists Fund of the National Natural Science Foundation of China (72103156).

assets are treated as separate asset classes. We calibrate/estimate the model using PSID data on the 1942 birth cohort. This cohort was age 26 in 1968 and reached age 77 in 2019, so we have close to a full life-cycle history on their behavior. Given our structural estimates of preferences, we can use the model to simulate the impact of favorable tax treatment of housing on the demand for housing, and on consumer welfare.

We conduct two types of experiments: First, we simulate scenarios where the 1942 cohort faces different tax rules. This allows us to ascertain how tax preferences affected their behavior. However, the 1942 cohort faced some unusual circumstances, such as very high interest rates from 1979 to 1990 that made the mortgage interest deduction (MID) very valuable when they were aged 37 to 48. This raises concerns that MID experiment results may not generalize to other contexts. Thus, in addition to the 1942-cohort model, we also consider a stationary model where tax rules, interest rates, rent and the real price of housing are fixed at year 2000 levels. Given our structural estimates of preferences we can simulate behavior given any constraints. We choose 2000 as interest rates, rent and the real price of housing were about average in 2000 relative to the whole sample period.

We find the favorable tax treatment of housing does increase home ownership for low and middle income households, but at a cost in economic efficiency. It leads to over consumption of owner-occupied housing relative to other goods. In both the 1942-cohort and stationary models, taxing imputed rent causes the ownership rate to drop by about 5 percentage points (pp). But it raises enough revenue to cut income tax rates by about 9%, and leads to a small drop in house prices. If agents are born into such a world, expected lifetime utility all types of households increases, giving a Pareto improvement. The average welfare gain is equal to about 0.8% of permanent income in both models.

Our simulations also show the mortgage interest deduction (MID) is regressive, as most benefits flow to higher income households who are induced to buy larger houses. Eliminating the MID and using the revenue to cut income taxes leads to 4.7% and 3.6% reductions in tax rates in the 1942-cohort and stationary models, respectively, and about a 1.7% drop in house prices in both models. The ownership rate drops very slightly. The average welfare gain is equal to 0.76% of permanent income in the 1942-cohort model, and 1.3% in the stationary model. All types are better off, so we have a Pareto improvement.

We also consider a policy of replacing MID with a refundable mortgage interest credit. A flat-rate credit of 18.5% is revenue neutral in the stationary model. This policy increases the ownership rate by 2.5pp, reduces house prices 1.45% in equilibrium, and increases average welfare by 1.14%. All types are better off, so we again have a Pareto improvement. In the 1942-cohort model results are slightly less favorable to this policy, as the wealthiest households, who benefited greatly from high value of MID in the ‘79 to ‘90 period, are worse off. Prior work has not simulated the impact of a refundable credit. Our results imply a credit policy can improve both housing affordability and overall welfare.

Our work is most related to papers by Gervais (2002), Chambers et al. (2009a,b,c), Cho and Francis (2011), Floetotto et al. (2016) and Sommer and Sullivan (2018). They analyze preferential tax treatment of owner-occupied housing in dynamic OLG models. In contrast, we estimate a life-cycle model for one cohort. We treat the house prices facing the cohort as exogenous, and estimate the model in partial equilibrium. We then embed it in an equilibrium model for policy experiments, assuming a simple supply side.

The advantage of estimating our life-cycle model, relative to calibrating an OLG model, is that we can model household decision making, and constraints households face, in much greater detail: We include more assets classes (owner-occupied and investment property, each financed by separate mortgages, plus liquid assets), and treat purchase of owner-occupied and rental property as separate decisions. We incorporate more household heterogeneity, including life-cycle patterns of income and family composition. We model the tax system in much greater detail than earlier papers, using actual tax parameters that existed annually from 1968-2019. We let house prices and interest rates vary over time, rather than assuming stationarity. Our model incorporates the decision to itemize, and captures the impact of changes in tax rules and nominal interest rates on the MID. And we fit the model to detailed micro data on life-cycle profiles of property ownership and financial assets, while the OLG papers only match a small set of aggregate statistics.

Given our structural estimates of preferences, we can simulate how households behave given any path of prices and taxes, including stationary and non-stationary environments.

2 Literature Review

Rosen (1985) surveys classic papers on demand for housing, including Laidler (1969), Rosen (1979), Rosen and Rosen (1980), Hendershott and Schilling (1982), King (1983). These papers regress demand for housing on the after-tax user cost of owner-occupied housing, along with income and demographic controls, relying on time-series/cross-section variation in user costs to identify the price elasticity of demand.

Under a "level" system, where the service flow from owner-occupied housing is taxed while associated costs are deductible, the after-tax user cost per dollar of housing services is simply $i+\tau_p+\delta$, where i is the mortgage interest rate, τ_p is the property tax rate and δ is the cost of depreciation and maintenance.[1] But the fact that the service flow from owner-occupied housing is not taxed, while mortgage interest and property tax are nevertheless deductible, reduces the after-tax user cost by $\tau(i+\tau_p)$, where τ is the marginal tax rate. This reduction can be substantial in higher tax brackets.[2]

[1] This assumes the mortgage rate equals the opportunity cost of funds, and that depreciation and maintenance are proportional to house value. In a level tax system the service flow from housing is taxed at rate τ, and all three costs of generating that flow are tax deductible. Thus taxation reduces both the service flow and the cost by τ%, so τ drops out of the after-tax user cost expression.

[2] For example, if i=6%, τ_p=1% and δ=3%, the true economic user cost is 10%. But for a person in a 40% tax bracket this is reduced by 28%, giving an after-tax user cost of only 7.2%.

As Hendershott and Schilling (1982) note, given house price appreciation at rate q the user cost is $(i + \tau_p)(1 - \tau) - q + \delta$. Mortgage interest is tax deductible while capital gains are untaxed, so the i term is multiplied by $(1 - \tau)$ but q is not. This means inflation – which raises the nominal interest rate i and the appreciation rate q by the same amount – will lower the user cost. Poterba (1984) noted that the impact of tax preferences on the user cost of housing is greatly amplified in an inflationary environment.

The consensus finding of papers surveyed by Rosen (1985) is that the price elasticity of demand for owner-occupied housing is about 0.5 to 1.0, and elimination of tax preferences would reduce the ownership rate from the roughly 64% that prevailed in the US for most of the post-war period to about 60%. But as Rosen (1985) notes, these studies have trouble explaining why ownership is so stable at about 64% despite large changes in user costs over time.[3] For example, user cost was driven to zero in the high inflation 70s, yet ownership rose by only one point. He argues that downpayment requirements, rationing of mortgage loans, and costly adjustment make it difficult for ownership to adjust quickly.

More recent work on demand for housing relies on models that make downpayment constraints and transactions costs explicit. This includes Gervais (2002), Chambers et al. (2009b), Cho and Francis (2011), Floetotto et al. (2016) and Sommer and Sullivan (2018), who analyze the impact of the preferential tax treatment of owner-occupied housing in dynamic overlapping generation (OLG) models. We now turn to those studies:

The classic paper by Gervais (2002) emphasizes the downpayment requirement and sets a minimum house size. Households must save the downpayment in order to buy, and they also save for retirement. But in other respects his model is simple: House size above the minimum is continuous, there are no long-term mortgage contracts, prices/taxes/interest rates are constant over time, taxes are flat, and there are no transaction costs. He finds that removing the mortgage interest deduction (MID) reduces the home ownership rate by 4 pp, while taxing imputed rents reduces it by 17 pp.

In Gervais (2002) model, anyone who can meet the downpayment requirement prefers owning to renting, due to favorable tax treatment of housing. As Henderson and Ioannides (1983) note, a more fundamental reason to prefer ownership is the high depreciation rate on rental property - arising because renters do not internalize costs of wear and tear - which drives up rents in equilibrium. Symmetrically, owners get greater utility from housing, as they are free to make utility enhancing modifications.

Cho and Francis (2011) extend Gervais (2002) to add transactions costs and a utility premium from ownership. Removing the MID has a negligible effect on the ownership rate in their model, but taxing imputed rent reduces it substantially from 64% to 41%.

[3]The ownership rate in the US was stable at about 64-65% from 1965-1995. In 1996-2005 it rose to 69%, but returned to the 64-65% range after the GFC. Chambers et al. (2009a) argue that the increase in 1996-2005 can be largely explained by low downpayment "combo" loans that attracted young households.

Floetotto et al. (2016) further extend Gervais 2002 by introducing less than perfectly elastic supply (the elasticity is 2.5), thus making house price endogenous. They also allow homeowners to rent out part of their property (thus becoming landlords). In their model, eliminating the mortgage interest deduction causes ownership to drop by 14pp, and taxing imputed rent causes it to drop dramatically by 32pp.

Importantly, Chambers et al. (2009b) extend this earlier work in three key ways: First, they emphasize the "lumpiness" of housing: In their model housing comes in discrete sizes. To change house size a household must sell the old house, buy a new one, and get a new mortgage. Both Ortalo-Magné and Rady (2006) and Ríos-Rull and Sánchez-Marcos (2008) argue it is important to model discrete house size to capture how households must accumulate progressively larger downpayments to move up the housing ladder over the life-cycle. Second, they introduce long-term mortgage contracts (i.e., a 30-year fixed-rate mortgage with a 20% downpayment). Third, they have progressive taxes. Their model is closest to ours, but prices/taxes/interest rates are still constant over time, there is no separate investment property, and no PTI constraint.[4] They do not endogenize price.

Chambers et al. (2009b) simulate that eliminating the mortgage interest deduction would *increase* the ownership rate from 64.6% to 65.3%, while average house size falls trivially. Similarly, taxing imputed rent actually *increases* the ownership from 64.6% to 67.6%, while reducing average house size by 2.1%. Both results are driven by falling tax rates in equilibrium (the interest rate falls very slightly). These results are radically different from those in Gervais (2002), Cho and Francis (2011) and Floetotto et al. (2016).

Sommer and Sullivan (2018) is similar to Chambers et al. (2009b), but house price is endogenized. They estimate a supply elasticity of 0.90.[5] On the other hand, the model is simplified three key ways: They do no have long-term mortgage contracts. The interest rate is fixed. And there is no retirement, so it is not a full life-cycle model. Sommer and Sullivan (2018) predict that eliminating the mortgage interest deduction would increase the home ownership rate from 65% to 70%. This is mostly because the price of housing falls by a substantial 4.2%. They do not simulate taxation of imputed rent.

Henderson and Ioannides (1983) emphasize that housing has a dual nature as both a consumption and investment good. If consumption demand exceeds investment demand a household may rent rather than own. Conversely, if the desired level of housing investment exceeds the desired level of housing consumption a homeowner may choose to acquire

[4]Their model has some problems in fitting the distribution of house sizes by age and income. Table 2 of the RED paper shows the model predicts an ownership rate that is too high at ages 35-74 and drops too much at 75+. In the data the home ownership rate is very flat at ages 50 to 80. One needs more life-cycle features to fit this. This is a key motivation for our life-cycle modeling approach.

[5]This is close to the 1.0 in Poterba (1984), but less than the 2.5 in Floetotto et al. (2016). As the long-run elasticity is controversial, in our experiments we consider both the unit elastic and infinitely elastic supply (i.e., fixed price) cases. When Sommer et al. (2013) assume housing stock is fixed, they find very large short-run effects of demand shifts on house prices.

investment property. The papers discussed so far do not capture this feature. But we emphasize this in our model by including a decision to buy investment property.

Berkovec and Fullerton (1992) calibrate a *static* general equilibrium model featuring the dual nature of housing. Households of many representative types allocate resources amongst housing, equities and bonds at the start of the single period, including making a decision to own vs. rent. Income and asset returns are revealed at the end of the period, and this determines non-housing consumption. The tax structure is modelled in great detail. However, this model abstracts from the lumpiness of housing investment, and because it is static it abstracts from transaction costs and long-term mortgage contracts.[6]

They simulate that taxation of imputed rent would raise enough revenue to scale down all tax rates by 10%. This causes the ownership rate to increase by 0.8%. But there is a substantial drop in demand for large houses among high income households, so the owner-occupied housing stock falls 2.8%. Eliminating the MID raises enough revenue to scale down all tax rates by 2.7%. Ownership is almost constant, but the owner-occupied housing stock falls 2.6%, with the drop concentrated among middle income households. This occurs because wealthy households can draw on other financial assets to reduce their mortgage debt, as discussed by Poterba and Sinai (2011). [7]

Clearly the literature has not reached a consensus on the impact of eliminating the favorable tax treatment of housing on home ownership. Gervais (2002), Cho and Francis (2011) and Floetotto et al. (2016) all predict large negative effects, the studies surveyed in Rosen (1985) predict more modest negative effects, Berkovec and Fullerton (1992) and Chambers et al. (2009b) predict very small positive effects, and Sommer and Sullivan (2018) predict fairly large positive effects.

In contrast to earlier papers, we estimate a life-cycle model instead of an OLG model. The advantage of our approach is that the computational saving from modeling a single cohort allows us to expand our model on several dimensions: Most importantly, we allow for changing house prices, changing tax structure and changing interest rates over time, rather than a stationary environment. The response of housing demand to these changing prices and taxes helps to identify the preference parameters in our model. We can then embed these preferences in a simple equilibrium model to do counterfactuals. We also estimate our model using method of simulated moments to fit many features of the micro data, rather than calibrating to a small set of macro statistics as in prior work.

[6]They assume a fixed cost of holding a positive position in any asset class. So, while there is no minimum house size or downpayment, it is not optimal for a household to hold a small amount of housing. The same is true for equities. The model takes the form of a multinomial logit for which set of assets a household will hold, where the key regressor is expected utility conditional on holding each set, assuming an optimal allocation of resources among the available assets in that set.

[7]Hendershott and Won (1992) calibrate a similar equilibrium model, but they do not simulate removing the favorable tax treatment of housing. Instead they simulate the effect of all provisions of TRA86, one of which was to reduce the importance of the mortgage interest deduction by lowering top rates.

3 A Life-Cycle Model of Demand for Housing

3.1 Overview

We present a life-cycle model of the demand for housing that we estimate using data on the 1942 birth cohort in the PSID, treating the historical house prices they faced as exogenously given. Later, we will also specify a very simple model of housing supply. Then, when we consider counterfactual experiments that alter the demand for housing, we will be able to solve for the new equilibrium price of housing.

We model the life-cycle housing and consumption/saving decisions of individual households. Each household is modelled as a unitary agent, regardless of household size. We will call the decision maker the household head. Thus, we will use the terms "agent," "household" and "household head" interchangeably. As we will see, household composition enters the model as a shifter of the head's preferences.

Agents (or household heads) enter the model at age 26, and make annual decisions about housing tenure (rent/own), home size, investment property holdings, liquid asset holdings and consumption. An agent survives from age $t-1$ to t with probability ρ_t, and dies with certainty at $T = 95$. As we model a single cohort, t denotes both age and year.

When agents enter the model at age 26 they have no property holdings. In subsequent periods they make decisions about property acquisition and sales. In any given period (year) the agent may be (i) a renter who holds no property, (ii) an owner-occupier, who owns and lives in a home, or (iii) a landlord who owns their own home and also owns a rental/investment house. These three states are mutually exclusive and exhaustive.[8]

Houses come in discrete sizes, ranging from 1 to 5-bedrooms. It is convenient to have separate indices for the size of owner-occupied and investment properties that a household may own at age t, so we denote these by j_t^o and j_t^k. If the agent owns no owner-occupied property at time t, then $j_t^o = 0$. If the agent owns no investment property at time t then $j_t^k = 0$. So $j_t^o \in \{0, ..., 5\}$ and $j_t^k \in \{0, ..., 5\}$. Finally, if a household rents rather than owns we let j_t^r denote the size house they rent at time t. We also have $j_t^r \in \{0, ..., 5\}$.

3.2 Utility Function Parameters

We let j_t denote the size house that an agent (household) lives in at age t. This may be an owner-occupied home or a rented home. Let $R(j)$ denote the housing service flow from a size j owner-occupied house. A household that rents receives a reduced service flow determined by the parameter $\mu \in (0, 1)$, consistent with the idea that a renter cannot modify a house to suit their tastes. Then, the service flow that a household receives from housing at age t is $R(j_t^o) + \mu R(j_t^r)$. Because we rule out owning and renting at the same time, we have $j_t^o \cdot j_t^r = 0$, so one component of this sum is always equal to zero.

[8] The data show few renters own an investment property, so we rule this out.

We also assume there exists a utility cost of moving from owner-occupier to renter status, Δ_s^o. This is meant to capture the idea that older people often seem averse to leaving their homes. And we assume there exist utility costs of becoming a landlord, or exiting landlord status, that we denote by Δ_b^k and Δ_s^k, respectively. These are meant to capture utility/time costs such as finding an agent, finding and dealing with tenants, learning about tax issues that arise from buying/selling investment property, etc.

Households derive utility from both housing and non-housing consumption. Letting C_t denote non-housing consumption and $d_t^H = \{j_t^o, j_t^k, j_t^r\}$ denote housing related choices, the period utility function is given by:

$$u_t(C_t, d_t^H) = \frac{C_t^{1-\gamma}}{1-\gamma} + \psi_t \frac{(R(j_t^o) + \mu R(j_t^r))^{1-\delta}}{1-\delta} - I_s^o \Delta_s^o - I_b^k \Delta_b^k - I_s^k \Delta_s^k \tag{1}$$

In order to include the utility costs of transitions we have defined the transition indicators:

$$I_{st}^o = 1 \text{ when } j_t^o = 0 \text{ and } j_{t-1}^o > 0, \text{otherwise } I_{st}^o = 0.$$
$$I_{bt}^k = 1 \text{ when } j_t^k > 0 \text{ and } j_{t-1}^k = 0, \text{otherwise } I_{bt}^k = 0.$$
$$I_{st}^k = 1 \text{ when } j_t^k = 0 \text{ and } j_{t-1}^k > 0, \text{otherwise } I_{st}^k = 0.$$

Note that j_t^k only affects utility through the utility costs of transitions.

The parameter ψ_t in (1) captures the relative preference for housing vs. non-housing consumption. We let ψ_t differ between households with and without dependent children. Amongst households without children, we also let ψ_t differ between households where the head is less than age 45 vs. age 45+. Thus we have:

$$\psi_t = \psi_1 K_t + \psi_0 (1 - K_t)(I[t > 45] + \psi_{0a} I[t \leqslant 45]) \tag{2}$$

Agents also receive utility from leaving bequests. Let W_t denote terminal net wealth, for an agent that dies at age t. This includes equity in owner-occupied and investment property plus liquid assets. As in Campbell and Cocco (2015), we assume bequest utility:

$$B(W_t) = \eta W_t^{1-\gamma}/(1-\gamma) \tag{3}$$

where the parameter η determines the strength of the bequest motive.

3.3 The House Price Process

We assume that house prices consist of a time-invariant component that is specific to each house size, times a time-varying price index. Let h^j denote the baseline price of a j-bedroom house. Let P_t^H denote the house price index. Then the price of a j bedroom house in year t is given by:

$$H_t(j) = P_t^H h^j \tag{4}$$

We normalize $P_t^H = 1$ when t corresponds to 1999, and allow the price to vary over time (1968-2019) according to the Case-Schiller index. Note that size-specific house price

indices do not exist, so it is not possible to generalize (4). We calibrate the relative house values $\{h^1, ..., h^5\} = (\$59.5k, \$70k, \$90k, \$120k, \$170k)$, using the median values of 1 to 5 bedroom owner-occupied homes in 1999, as explained in Section 5.2.

In our model agents take expectations over potential future house price movements when making decisions about buying and selling property. It is important to distinguish expected vs. actual (realized) price movements: Realized prices in our model follow the Case-Schiller index. But we assume that agents form one-year ahead expectations of real house price appreciation according to the following multinomial distribution:

$$P^H_{t+1} = P^H_t(1 + \varepsilon_{h,t+1}) \quad \text{where} \quad \varepsilon_{h,t+1} \sim MN(-5\%, +1\%, +7\%;\ 1/3, 1/3, 1/3) \tag{5}$$

Equation (5) says that agents expect the real house price may increase by 7% or 1%, or decrease 5%, with probability 1/3 each. Thus the expected increase is 1.0% annually, and the standard deviation is 4.9%. This is consistent with the mean and standard deviation of the annual growth rate of the Case-Schiller index in real terms from 1968 to 2019.

3.4 Housing Supply

Following Sommer and Sullivan (2018), Floetotto et al. (2016) and Poterba (1984), we assume iso-elastic supply of the total stock of housing. The total stock of housing H is the total number of owner-occupied houses weighted by house size, plus the total number of apartments weighted by apartment size, $H_t = \sum_i j^k_t(i) + \sum_i j^k_t(i)$, where i indexes households. The iso-elastic supply is $P^H_t = (H_t)^{1/\eta}$ where η is the supply elasticity.

3.5 Housing Cost Parameters

Here we define cost parameters for owning houses and we express them as proportions of house value. We assume owner-occupied houses depreciate at the rate δ^o. To prevent depreciation, we assume owner-occupiers must pay an annual maintenance fee of δ^o times the house value. Other homeowner expenses are the annual property tax payment τ^o and the usage fee ϕ^u, which includes electricity bills, water bills, gas bills, and other utilities.

The mortgage payment depends on the mortgage balance on the owner-occupied house, which we denote by M^o_t. The household's beginning of period t mortgage payment equals $M^o_{t-1}(1 + r_m) - M^o_t$, as we explain in more detail Section 3.7. So we can write the annual housing cost for an owner-occupied house $Hcost^o_t$ as:

$$Hcost^o_t = H_t(j^o_t)(\phi^u + \tau^o + \delta^o) + M^o_{t-1}(1 + r_m) - M^o_t \tag{6}$$

The annual cost of owning an investment property includes the property tax τ^k, the depreciation δ^k and the mortgage payment. It does not include the annual running costs ϕ^u as that is paid by the tenants. A landlord faces higher depreciation and property tax rates, and a higher mortgage interest rate, than an owner-occupier; see Section 5.1.

We assume renters pay α times the house value as rent, and this rent is income for the landlord. (Later, we calibrate α so landlords break even on average.) To account for various costs confronting landlords, such as costs of finding tenants, agent commission fees, costs of collecting rent, time in between renters (when a property goes unoccupied), we assume the landlord only receives a fraction s^k of the rental income. Then, the annual net cost of holding an investment property is:

$$Hcost_t^k = H_t(j_t^k)(\tau^k + \delta^k - \alpha \cdot s^k) + M_{t-1}^k(1 + r_m^k) - M_t^k \tag{7}$$

In addition, buying and selling a house incur monetary transaction costs (i.e., realtor's fees, closing costs) and we denote these by ϕ^b and ϕ^s. Changing house size requires selling the old house and buying a new house, so both the selling and buying costs apply.

3.6 Financial Assets

A household can invest its (non-negative) stock of savings S_t in one financial asset: a riskless bond. No transaction costs are incurred when these assets are traded. The risk-free rate is denoted r^f, and we define $R^f = 1 + r^f$.

3.7 Mortgage Loans

We assume a house can only be purchased by acquiring an m-year fixed-rate mortgage loan with a σ percent downpayment. Households are liquidity constrained and cannot have uncollateralized debt. Thus, they must be able to afford the downpayment to buy a house. We set m=30 and $\sigma = 0.20$, and set the real mortgage interest rate to r_m=5%. The mortgage amortization schedule is set at mortgage initiation.

Letting M_0^o denoted the initial mortgage, the fixed annual mortgage payment is:[9]

$$MP^o = \frac{r_m}{1 - 1/(1 + r_m)^{30}} M_0^o \tag{8}$$

Letting M_{t-1}^o denote the mortgage balance for an owner-occupied house at time t, the law of motion for the mortgage balance is:

$$M_t^o = (1 + r_m)M_{t-1}^o - \left[\frac{r_m}{1 - 1/(1 + r_m)^{30-t_m+1}}\right] M_{t-1}^o \tag{9}$$

where $t_m = 1, ..., 30$ denotes years into the mortgage term (distinct from t which denotes the model period). If we set $t_m = 30$ we obtain $M_t^o = 0$ so the mortgage is paid off.

Although the payments on a particular mortgage are fixed over time, it will be useful to adopt the notation MP_t^o to indicate that a household's mortgage payment may vary over time as they change their real estate holdings (e.g., buy a larger house and acquire

[9]For example, for a $100k$ 30-year 5% mortgage the fixed annual payment is \$6505. Given fixed payments, the homeowner pays mostly interest at first, while in later years they pay more principal.

a larger mortgage). The household's beginning of period t mortgage payment can be written $MP_t^o = r_m M_{t-1}^o + (M_{t-1}^o - M_t^o) = M_{t-1}^o(1 + r_m) - M_t^o$, which includes the interest payment and the paydown of principal.

Similarly, for an investment property, the mortgage balance in year t is denoted M_t^k, and it evolves in the same way as in equation (9), except that the interest rate r_m^k is higher. We denote the mortgage payment on an investment property as MP_t^k.

Households must make regular mortgage payments each year. If the household lacks sufficient liquid assets to make its mortgage payment, it must sell the property to cover the cost. An owner-occupier who cannot make the mortgage payment must either downsize or switch to renting. A landlord who cannot make the payment on an investment property must either sell and shift to a smaller investment property or cease to be a landlord.

Recall that if an agent changes the size of their house (upsize or downsize) he/she must sell the original house, buy a new house, and obtain a new mortgage. We assume that any equity from the original house is carried over to the new house. If that equity exceeds the required 20% downpayment for the new house, the agent makes a larger downpayment (i.e. equal to the full amount of the equity). If the original equity exceeds the entire cost of the new house, then the agent buys the house outright with no mortgage, and any excess equity is converted to liquid assets.

3.8 Payment to Income (PTI) Constraint

In addition to downpayment requirements, a key additional feature of mortgage loans is that banks impose a maximum housing payment-to-income (PTI) ratio on borrowers. Prior work has modeled the downpayment constraint but not the PTI constraint. Housing payments include the mortgage payment itself, along with maintenance, tax and usage costs. To qualify for a loan, the ratio of housing payments to *gross* income – called the "front-end" PTI ratio – should not exceed the maximum PTI constraint.[10] According to Bunce et al. (1995), see p. 6-11, the maximum "front end" PTI is typically set at 28%, but banks have leeway to vary this based on individual circumstances.

The annual housing payment for a prospective homeowner, denoted $Hpay^o$, accounts for all costs used by banks to calculate PTI, including usage costs ϕ^u, property tax τ^o, depreciation δ^o, and the annual mortgage payment MP^o as determined by equation (8). The predicted annual payment for an investment property is similar, so we have:

$$Hpay^o = H_t(j_t^o)(\phi^u + \tau^o + \delta^o) + MP^o \tag{10}$$

$$Hpay^k = H_t(j_t^k)(\phi^u + \tau^k + \delta^k) + MP^k \tag{11}$$

[10] Banks also consider the back-end PTI ratio, also called the debt-to-income ratio (DTI), which is the percentage of gross monthly income spent on debt payments including not only housing costs but also student loans, auto loans, personal loans, etc. According to Bunce et al. (1995), p.6-11, the maximum "back end" PTI is typically 36%. Our model abstracts from the fact that borrowers may have other debt like auto loans, student loans and consumer debt, so we ignore the DTI constraint.

To calculate gross income, we assume that banks use the household's *expected* earnings plus interest income. According to Fannie Mae (2023), for an investment property, 75% of rental income can typically be counted in the PTI constraint. So we have:

$$\bar{Y}_t = E(Y_t) + S_{t-1} \cdot r^f + \alpha \cdot 0.75 \cdot H_t(j_t^k) \tag{12}$$

$$\{Hpay^o + Hpay^k \cdot I(j_t^k > 0)\}/\bar{Y}_t \leqslant PTI \tag{13}$$

The PTI constraint applies whenever a new house is purchased, either in the case of a renter buying a home, homeowners resizing their owner-occupied houses, homeowners purchasing an investment property, or landlords resizing their investment property. All these events require new mortgage loan applications.

3.9 Tax Policy

We model US tax rules from 1968-2019 in some detail. The federal income tax is determined by plugging taxable income into a progressive tax formula, where the tax brackets and rates within each bracket change annually. Taxable income Y_t^{tax} is equal to gross income Y_t^g minus the personal and dependents' exemption D_t^p and *either* the standard deduction D_t^S or the itemized deduction D_t^I, whichever is larger, as in:

$$Y_t^{tax} = Y_t^g - D_t^p - D_t^{Max} \tag{14}$$

$$D_t^{Max} = max\{D_t^I, D_t^S\} \tag{15}$$

We account for how D_t^S and D_t^p have changed over time.

For both home owners and renters, gross income is simply earnings plus interest. For a home owner, the itemized deduction D_t^I includes mortgage interest payments, $M_t^o i_{mt}$, property tax payments, $H_t(j_t^o)\tau^p$, and state income tax payments, while renters can only deduct state tax. We use the nominal interest rate i_{mt} to calculate the MID, rather than the real rate, to capture how inflation reduces the user cost of housing.

Then, letting $O_t = I[j_t^o > 0]$ be an indicator function equal to one if the household owns its own home at time t, and equal to zero if the household rents, we have:

$$Y_t^g = Y_t + S_{t-1} r^f \tag{16}$$

$$D_t^I = (M_t^o i_{mt} + H_t(j_t^o)\tau^o + T_t^s)O_t + T_t^s(1 - O_t) \tag{17}$$

$$T_t^s = r^s \cdot (Y_t^g - \vartheta) \cdot I(Y_t^g > \vartheta) \tag{18}$$

where T_t^s denotes state tax. We do not model individual State tax rules in detail, but instead assume a flat rate r^s above a state standard deduction ϑ.

Next we consider landlords: The *only* difference here is that gross income Y_t^g also includes the *net* income they earn on the investment property. This net income is rent minus all expenses of earning that income, D_t^E, which includes mortgage interest, prop-

erty tax payments and maintenance costs. And Y_t^g also includes capital gains on the investment property, CG_t. So we have:

$$Y_t^g = Y_t + S_{t-1}r^f + I(j_t^k > 0)[H_t(j_t^k) \cdot \alpha \cdot s^k - D_t^E + CG_t] \tag{19}$$

$$D_t^E = M_t^k r_m^k + H_t(j_t^k)(\tau^k + \delta^k) \tag{20}$$

$$CG_t = (H_t(j_t^k) - H_{t-1}(j_t^k)) \cdot I(j_t^k = j_{t-1}^k) - I_{st}^k \cdot \phi^s H_t(j_{t-1}^k) - I_{bt}^k \cdot \phi^b H_t(j_t^k) \tag{21}$$

Handling capital gains correctly is computationally very difficult as it requires keeping track of the value of the house at the time of purchase as an additional state variable. For this reason the prior literature in this area has ignored capital gains.[11] To finesse this problem, we assume that capital gains are taxed on an accrual basis. Gains and loses in the value of the investment property are counted as part of gross income in the year they occur. So the year t capital gain/loss on an investment property is the increase/decrease in value from the prior year, as indicated in equation (21).[12] Selling costs are a deduction in the year the house is sold, and buying costs a deduction the year it is bought.

Finally, we define the federal tax function $T_t(Y_t^{tax})$. It has a progressive structure, with brackets and rates that differ by year. In years when the structure is more progressive, the mortgage interest deduction is more valuable for high-income households.

3.10 Household income and kids processes

We define Y_{it} as the total household income of household i at age t, *excluding* interest on savings and rental income. Y_{it} includes total family labor income, as well as social security, child support, pensions, etc. We model the income process separately for households where the head has each of three levels of education: college, some college, or high school (or less). We also allow for three latent types within each education category.

Conditional on the education level of the household head, Edu_i, we model the household income process as a polynomial in age A_{it}, the indicator for having kids, K_{it}, and an indicator for age over 65, $D65_{it}$:

$$log(Y_{it}|Edu_i, \mu_i) = l_0 + l_1 A_{it} + l_2 A_{it}^2 + l_3 A_{it}^3 + l_5 D65_{it} + l_6 K_{it} + \mu_i + \varepsilon_{it} \tag{22}$$

$$\mu_i \sim MN(-\mu_{Low}, 0, \mu_{High};\ \ 1/3, 1/3, 1/3) \tag{23}$$

$$\epsilon_{it} \sim MN(-\epsilon_{Low}, 0, \epsilon_{High};\ \ 1/3, 1/3, 1/3) \tag{24}$$

The term μ_i in (22) is the time-invariant latent income type of the household, which can be 'low', 'middle'(0), and 'high' with probability 1/3 each. As we have three education types and three latent μ types, we have nine exogenous income process types in total.

[11] In Chambers et al. (2009b) a random capital gain/loss shock is revealed *after* a house is sold. In their model the house price is constant, so this is not a capital gain in our sense.

[12] That is, if the value of your house goes up from last year, you pay tax on the increase immediately. Hence there is no tax when you sell. You have already paid tax on past capital gains on an accrual basis.

We also assume the time-varying stochastic earnings shock ε_{it} is multinominal with three possible values, as we see in (24). The assumption that it takes three values simplifies the solution of the dynamic optimization problem.

The indicator for having dependent children K_{it} evolves according to the logit model:

$$\frac{P(K_{it}=1)}{1-P(K_{it}=1)} = exp(a_0 + a_1 A_{it} + a_2 A_{it}^2 + a_3 A_{it}^3 + a_4 K_{i,t-1} + a_5 Edu_i) \tag{25}$$

We describe the calibration of the income and kids processes in Section 5.3.

3.11 Budget Constraint

At the start of each period, a household's "full income," or total available resources, which we denote by W_t, consists of their exogenous income, Y_t, savings, $S_{t-1}R_t^f$, and their total equity in owner-occupied and investment property. So we have:

$$W_t = Y_t + S_{t-1}R_t^f + \{H_t(j_{t-1}^o) - M_{t-1}^o(1+r_m)\} + \{H_t(j_{t-1}^k) - M_{t-1}^k(1+r_m^k)\} \tag{26}$$

To understand the equity terms, note that if an owner-occupier at time $t-1$ were to sell their house at the start of period t, then, in lieu of making a time t mortgage payment, they would instead pay off the balance of the time $t-1$ mortgage balance plus interest, $M_{t-1}^o(1+r_m)$, and they would receive the time t value of the house $H_t(j_{t-1}^o)$. They would also pay selling costs, which we count as a time t expense in equation (27) below.

The household's full income is allocated to non-housing consumption C_t, savings at the end of period t, S_t, the tax payments $T_t(Y_t^{tax})$ and T_t^S, home and investment property equity at the end of period t, house buying and selling costs, and the sum of house maintenance, usage, and property tax costs (net of any rental income). For renters we have rent and usage costs. Thus the intertemporal budget constraint for the period t is:

$$\begin{aligned} W_t = {} & C_t + S_t + T_t(Y_t^{tax}) + T_t^s + (H_t(j_t^o) - M_t^o) + (H_t(j_t^k) - M_t^k) \\ & + \phi^b H_t(j_t^o) I_{bt}^o + \phi^s H_t(j_{t-1}^o) I_{st}^o + \phi^b H_t(j_t^k) I_{bt}^k + \phi^s H_t(j_{t-1}^k) I_{st}^k \\ & + H_t(j_t^o)(\phi^u + \tau^p + \delta) + H_t(j_t^k)(\tau^p + \delta - \alpha \cdot s^k) + H_t(j_t^r)(\alpha + \phi^u) \end{aligned} \tag{27}$$

where the indicator I_{bt}^o for buying an owner occupied-house is defined as:

$$I_{bt}^o = 1 \text{ when } j_t^o > 0 \text{ and } j_{t-1}^o = 0, \text{otherwise } I_{bt}^o = 0. \tag{28}$$

and the other three transition indicators were defined in Section 3.2.

To allay potential confusion created by the generality of equations (26) and (27), consider a homeowner who does not have any rental property, and who stays in the same house from one year to the next, so $j_t^o = j_{t-1}^o$. Equation (27) then reduces to simply:

$$\begin{aligned} & Y_t + S_{t-1}R_t^f + \{H_t(j_t^o) - M_{t-1}^o(1+r_m)\} \\ & \qquad = C_t + S_t + T_t(Y_t^{tax}) + T_t^s + (H_t(j_t^o) - M_t^o) + H_t(j_t^o)(\phi^u + \tau^p + \delta) \end{aligned}$$

We can re-arrange this to read:

$$Y_t + S_{t-1}R_t^f = C_t + S_t + T_t(Y_t^{tax}) + T_t^s + (M_{t-1}^o(1+r_m) - M_t^o) + H_t(j_t^o)(\phi^u + \tau^p + \delta) \quad (29)$$

where $(M_{t-1}^o(1+r_m) - M_t^o)$ is the mortgage payment. So equation (29) says that income plus start of period assets equals the sum of consumption, end of period savings, the mortgage payment, and other housing costs (usage fees, property tax and maintenance).

Note that in equation (27) the rent payment enters the budget function for renters but not for homeowners. This means that owner-occupied homes provide implicit rental income for homeowners that cancels out their rent payment.

We also impose the constraints that consumption must be positive, and that there is no un-collateralized borrowing, so financial assets cannot be negative:

$$C_t > 0, S_t \geqslant 0 \quad (30)$$

Thus, households cannot borrow against future income to finance current consumption.

A state can arise where a low income household – particularly one lacking significant savings or home equity – cannot afford both positive consumption and the cost of living in the smallest (one-bedroom, j=1) house. We assume there exists a government welfare program that provides both (i) a minimum guaranteed consumption level, \$6000,[13] and (ii) a free 0.5 bedroom apartment. This is denoted by j=0, and we normalize $R(j=0) = 0.5$. Before using this program the household must first spend down all its assets.

4 Household's optimization problem

In each annual period, the household makes choices about the size of house to live in, whether to own or rent, whether and what size investment property to own, and how much to consume/save. It simplifies the computation to discretize the consumption possibilities, so the choice set is completely discrete, as in Keane and Wolpin (2001).

4.1 State Space

The initial state of a household at $t = 0$ when the head is age 25 is $X_0 = \{Edu, \mu, K_0\}$. It depends on the education and income type μ of the household head, which together determine the household's income profile, and whether children are present. In subsequent periods $t = 1, ..., 70$ the state evolves as the household makes decisions about housing, investment property and consumption, as house prices, income and kids evolve, and as mortality is revealed. We will call t the model age of the household, while biological age is $t + 25$. So the first decision period is age 26. Mortality is certain at $T = 71$ (age = 96).

[13] Note that the poverty line in 1999 was \$8240 for a single and \$2820 for each additional person. In our calibrated model, the implicit rent on an 0.5 room apartment is (1/2)(0.10)(59500) = \$2,975.

At the start of annual period t, the state space of a household can be written:

$$X_t \equiv \{H_t(j^o_{t-1}), M^o_{t-1}, H_t(j^k_{t-1}), M^k_{t-1}, S_t, Edu, \mu, K_t, Y_t\} \tag{31}$$

The first state variable is the value, *at the start of period* t, of the owner-occupied house of size j^o_{t-1} that the household occupied at the end of period $t-1$. This value $H_t(j^o_{t-1})$ is known because the house price index is revealed at the start of period t. The second state variable M^o_{t-1} is the mortgage balance on the house at the end of period $t-1$.[14]

The third and fourth state variables are the investment house value at the start of period t, and mortgage at the end of period $t-1$, denoted $\{H_t(j^k_{t-1}), M^k_{t-1}\}$. They evolve in an analogous way to the state variables for the owner occupied house.

The fifth state variable is savings at the start of period t. The sixth and seventh state variables $\{Edu, \mu\}$ determine the household's earnings type. The eighth state variable is whether the household has children at the start of t. At the start of period t, the stochastic part of income ϵ is drawn (see equation 24), and income Y_t is revealed.

4.2 Choices

The choice set may be written $d_t = \{j^o_t, j^k_t, j^r_t, C_t\}$ where the first argument is the size of the house owned, the second argument is the size of the investment property owned, the third argument is the size of house that one rents, and the fourth argument is discrete consumption. Of course there are important restrictions on this choice set. Having an owner-occupied house and renting are mutually exclusive, so $j^o_t \cdot j^r_t = 0$. We also assume that renters cannot own investment property, so $j^k_t \cdot j^r_t = 0$. Thus the housing choice set size is $5 + 5 \cdot 5 = 30$. We also allow for 12 discrete consumption levels, so there are 360 possible discrete choices each period. It will be useful to define $d^H_t = \{j^o_t, j^k_t, j^r_t\}$.

4.3 The Dynamic Optimization Problem

At any age t the objective of a household in state X_t is to choose $d_t = \{d^H_t, C_t\}$ to maximize the expected present value of remaining lifetime rewards:

$$V_t(X_t) = \underset{d^H_t, C_t}{max}\, E\left\{ \sum_{\tau=t}^{min\{T^d, T\}} \beta^{\tau-t}\big[\rho_\tau(u_\tau(C_\tau, d^H_\tau) + v_\tau) + (1-\rho_\tau)B(W_\tau)\big] | X_\tau \right\} \tag{32}$$

subject to the budget constraints in (27), the non-negativity constraints in (30), the PTI constraint in (13), the law of motion for mortgage balances in (9), the laws of motion

[14] To clarify our timing conventions, consider an example: Suppose that in period t the household chooses to remain in the same house. Then they choose $j^o_t = j^o_{t-1}$, and make the mortgage payment $MP^o_t = M^o_{t-1}(1+r_m) - M^o_t$. And at the start of period $t+1$ the first two state variables will be $\{H_{t+1}(j^o_t), M^o_t\}$. Alternatively, if the household wants to change house size, they choose $j^o_t \neq j^o_{t-1}$. Then, they must pay off the mortgage balance plus interest, $M^o_{t-1}(1+r_m)$, and they receive as the sale price the time t value of the house $H_t(j^o_{t-1})$. They then buy a new house and obtain a new mortgage. At the start of period $t+1$ the first two state variables are again denoted $\{H_{t+1}(j^o_t), M^o_t\}$, but the numerical values of these two state variables are of course different from the previous case.

for the exogenous state variables (house price, income, kids) in (4), (22), (25), the price expectation process in (5), and the choice set constraints discussed in Section 4.2.

Here T^d is the stochastic age of death and ρ_t is an indicator for survival to age t. We take mortality probabilities from the 1998 US life tables (CDC 2001). The term $v_t = \lambda^c v_{ht} + \lambda^h v_{ct}$ is a taste shock associated with each discrete choice. Its components v_{ht} and v_{ct} are specific to housing and consumption choices, as we now explain.

4.4 Solving the Dynamic Optimization Problem

We adopt the assumption that decisions within period t are made sequentially. In the first sub-period the household makes its decision about the housing related options $d_t^H = \{j_t^o, j_t^k, j_t^r\}$, and in the second sub-period it chooses consumption C_t.[15] Once the housing decision is made, the state of the household can be written:

$$X_t^h \equiv \{H_t(j_t^o), M_t^o, H_t(j_t^k), M_t^k, S_t, Edu, \mu, K_t, Y_t\} \tag{33}$$

Note that the utility function in (1) can be decomposed as $u_t(C_t, d_t^H) = u_t(C_t) + u(d_t^H)$. Utilizing this fact, the optimal consumption decision can be written:

$$C_t^* = \underset{C_t}{argmax}\{u(C_t) + \lambda^c v_{c_t} + \beta EV_{t+1}(X_{t+1}|X_t^h, C_t)\} \tag{34}$$

Here v_{c_t} is an *iid* extreme value error that captures taste shocks associated with each discrete consumption option, and λ^c is a scaling parameter that determines the importance of these shocks.

The term $EV_{t+1}(X_{t+1}|X_t^h, C_t)$ is the expected value of next period's state that arises from today's state and choice. The agent must take an expectation as X_{t+1} cannot be predicted perfectly based on $\{X_t^h, C_t\}$. This is because the realizations of next period's house price index, income, and kids at home will only be revealed at the start of time $t+1$. The agent must integrate over these three variables to take the expectation. Furthermore, there is a probability $1 - \rho_t$ the agent will die at the start of $t+1$, in which case the expected value of next period's state is simply the bequest function in (3).

We save the expected maximum value from solving the problem in (34) as $IC_t(X_t^h)$:

$$IC_t(X_t^h) = \underset{C_t}{Emax}\{u(C_t) + \lambda^c v_{c_t} + \beta EV_{t+1}(X_{t+1}|X_t^h, C_t)\} \tag{35}$$

The function $IC_t(X_t^h)$ summarizes all the agent needs to know about the second sub-period to make the optimal housing choice in the first sub-period.

[15] Alternatively, one could say we adopt a two-level nested logit model, where housing related choices are in the top nest and consumption choices are in the bottom nest. The nested logit is often interpreted as implying sequential decisions, but no temporal ordering is required. Instead, the substantive assumption of the nested logit model is that errors are independent within each nest. This allows us to avoid the assumption that v_t in (32) is *iid* distributed across the entire discrete choice set of 360 options. Instead we only assume independent errors across the subset of choices within each nest.

Now we turn to the choice amongst housing options in the first sub-period. Here the household chooses $d_t^H = \{j_t^o, j_t^k, j_t^r\}$. The choice problem at this stage can be written:

$$d_t^{H*} = \underset{d_t^H=\{j_t^o,j_t^k,j_t^r\}}{argmax} \left[u(d_t^H) + \lambda^h v_{d_t^H} + IC_t(X_t^h | X_t, d_t^H) \right] \tag{36}$$

Here $v_{d_t^H}$ is an *iid* extreme value error that captures taste shocks associated with each discrete housing option, and λ^h is a scaling parameter. We set $\lambda_t^h = \lambda^h \cdot (\theta_h)^t$ so λ_t^h may vary with age. Note that X_t^h is completely determined by X_t and d_t^H. Thus, the agent knows with certainty the inclusive value from the second sub-period consumption optimization problem that will arise from any first sub-period choice of d_t^H.

We can now write the value function associated with being in state X_t at the start of period t, which we presented in (32), in the more useful form:

$$V(X_t) = \underset{d_t^H}{Emax} \left[u(d_t^H) + \lambda^h v_{d_t^H} + IC_t(X_t^h | X_t, d_t^H) \right] \tag{37}$$

As we explain in Section 4.5, the equations (35) and (37) have closed form solutions.

A full solution of the household's dynamic optimization problem requires solving for $V(X_t)$ at every possible state point X_t. But this is infeasible due to (i) the large size of the state space, and (ii) the fact that at each state point the household has 360 choices, so the computational burden of solving for $V(X_t)$ at each *individual* state point is substantial. Perhaps surprisingly, given our detailed modeling of the tax system, the calculation of the tax bill at each (X_t, d_t^H) combination poses a very substantial burden all by itself.

To deal with this curse of dimensionality problem we adopt the solution proposed by Keane and Wolpin (1994) of evaluating $V(X_t)$ at only a subset of possible state points, and then using a fast interpolation method to fill in values at other state points as required during the remainder of the solution process.

Recall that X_t=$\{H_t(j_{t-1}^o), M_{t-1}^o, H_t(j_{t-1}^k), M_{t-1}^k, S_t, Edu, \mu, K_t, Y_t\}$. The last four state variables take on a manageable number of discrete values, so we solve at all of these. But the first five (house and mortgage values, savings) cause a problem, as they are continuous. So we solve for $V(X_t)$ on the discrete grid $X_t^g = \{H^{og}, M^{og}, H^{kg}, M^{kg}, S^g, Edu, \mu, K_t, Y_t\}$ for $g = 1, ...G$. We then set up a five dimensional interpolation function, that lets us predict $V(X_t^p)$ at any desired point $X_t^p = \{H^{op}, M^{op}, H^{kp}, M^{kp}, S^p, Edu, \mu, K_t, Y_t\}$ based on the $2^5 = 32$ nearest neighbor points on the grid.[16]

To set up the grid, we use 6 grid points for house values (zero and the median price of 1 through 5 bedroom houses),[17] 5 grid points for mortgage values (0, 20, 40, 60 and 80%

[16] In a one-dimensional interpolation problem there are two nearest-neighbor grid points that "straddle" the desired state point – the grid points that lie directly below and above it. In a two-dimensional problem there are $2^2 = 4$ nearest-neighbor grid points that "straddle" the desired point state point (i.e., both grid points could lie just above the desired point, both just below, or one just above and one just below). In a 5-dimensional interpolation there are $2^5 = 32$ grid points that straddle any desired point.

[17] For a house value above the highest grid point, we extrapolate by converting the extra house value

of house value), and 11 grid points for savings.[18] We let the grid points for house values drift up at 1.0% per year, to match the average increase in the Case-Schiller index.

4.5 Closed Form Solutions and Backsolving

As the taste shocks v_{d^H} and v_c in (35) and (37) have *iid* extreme value distributions, the integrals over these shocks have simple log-sum formulas, see Rust (1987):

$$V_t(X_t) = \lambda^h ln \sum_{d_t^H} exp\left[\frac{1}{\lambda^h}\{u(d_t^H) + IC_t(X_t^h|X_t, d_t^H)\}\right] \tag{38}$$

$$IC_t(X_t^h) = \lambda^c ln \sum_{C_t} exp\left[\frac{1}{\lambda^c}\{u(C_t) + \beta EV_{t+1}(X_{t+1}|X_t^h, C_t)\}\right] \tag{39}$$

We solve the dynamic programming problem by backsolving from the final period. Note that at time $T+1$ the household head dies with certainty, so we have simply $EV_{T+1}(X_{Y+1}|X_T^h, C_T) = B(W_{T+1})$ where B is the bequest function in (3) and W_{T+1} is the terminal wealth that remains after the household's final consumption choice. This includes remaining liquid assets plus an equity in an owner-occupied home and any investment property. Hence we have:

$$IC_T(X_T^h) = \lambda^c ln \sum_{C_T} exp\left[\frac{1}{\lambda^c}\{u(C_T) + \beta B(W_{T+1})\}\right] \tag{40}$$

Equation (40) has a simple closed form, so we can use this to start the backsolving process from time T. Given that it is simple to calculate $IC_T(X_T^h)$ at any state point X_T^h, we can plug this into (38) to obtain a closed from expression for $V_T(X_T)$. Which, in turn, we can plug into (39) to obtain $IC_{T-1}(X_{T-1}^h)$.[19] And so on working backwards to $t = 1$.

5 Calibration and Estimation

Our model contains three types of parameters. We can calibrate some parameters based on prior literature or knowledge of the US housing market (e.g., home buying costs). We can estimate some parameters outside the model (income, kids and house price processes). Finally, we have utility parameters that must be structurally estimated, as they are not directly observable but must instead be inferred from choice behavior.

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into savings, and calculating the impact of that extra savings on the value function. This provides a very stable way to extrapolate beyond the edge of the grid.

[18] The savings grid points are, in 1999 dollars: 0, 2549, 9153, 20561, 41152, 72194, 119,000, 202743, 413950, 785403, 1407425. These are the 10 to 90, 95 and 97.5 percentiles of real financial assets for our cohort. We extrapolate above the top of the grid by assuming all extra assets must be consumed immediately at t+1. Hence the utility function allows us to calculate the value of the extra assets.

[19] At this point, if we require $V_T(X_T)$ at a state point X_T that is not on our grid, we interpolate.

5.1 Calibrated Parameters

The parameters that we calibrate are listed in Table 1. Home buying costs include loan origination fees, escrow fees and legal fees, and title insurance, as well as moving costs. The seller pays the realtor's commission, which is typically 5 to 6 percent. We decided to set both the buying and selling costs to 5.5% of the home value.[20]

Table 1: Calibrated Parameters

Parameter	Description	Value
Housing costs		
ϕ^b	Purchase costs of houses	.055
ϕ^s	Selling costs of houses	.055
ϕ^u	Annual running cost	.022
δ^o	Depreciation rate, Own House	.020
δ^k	Depreciation rate, Rental House	.0244
τ^o	Property tax rate, Own house	.015
τ^k	Property tax rate, Rental house	.020
PTI Constraint		
PTI	Max Payment to Income Ratio	.280
Interest rates		
r^f	Risk-free interest rate	.030
r_m	Mortgage interest rate	.050
r_m^k	Mortgage interest rate, Investment	.0575
Rent Parameters		
α	Rent to Value ratio	.100
s^k	Landlord's Share of Rent	.910
Utility function		
$1-\rho_t$	Mortality rate, 1998 US life table	
β	Discount factor	.950
State income tax		
r^s	State tax rate	3%
ϑ	Deduction	\$10k

The median utility expense for homeowners in the 1999 PSID was \$2160.[21] This is approximately 2.2% of the median house value of \$99k. Hence, we set the annual running cost for a house (e.g., utilities) to ϕ^u=2.2% of the house value. Similarly, Poterba (1992) sets the running cost to 2%.

The US tax code allows 3.636% annual depreciation on *structures*. According to Case (2006) land was 1/3 of the value of homes in 1990. This implies an *overall* δ^k=2.44% annual depreciation rate for investment property. We assume a lower rate of δ^o=2% on owner-occupied property, as in Poterba (1992). As for property tax, according to Lincoln Institute of Land Policy (2018) the average property tax rate for owner-occupied homes in the US is $\tau^o = 1.5\%$, while the average rate on rental property is $\tau^k = 2\%$.

[20] The literature is very mixed on these settings. Both Sommer and Sullivan (2018) and Cho and Francis (2011) set ϕ^b=2.5% and ϕ^s=7%, while Floetotto et al. (2016) set ϕ^b=2.5% and ϕ^s=6%. But Chambers et al. (2009b) set ϕ^b=6% and ϕ^s=0.

[21] We obtain a similar figure of \$2377 for 1999 from the Consumer Expenditure Survey, U.S. Bureau of Labor Statistics, Expenditures: Utilities, Fuels, and Public Services: All Consumer Units, retrieved from https://fred.stlouisfed.org/series/CXUUTILSLB0101M, February 8, 2024.

We set the real risk-free rate to 3%, and the real mortgage interest rate to 5%. Similarly, Campbell and Cocco (2015) assume the mortgage rate is 1.8pp higher than the 10-year Treasury bill rate. The mortgage rate on investment property typically exceeds that on owner occupied homes by about 0.75pp, so we set it to 5.75%. The nominal mortgage interest rates we use to calculate the MID are taken from Freddie Mac 2022. Notably, these exceed 10% from 1979-1990, making MID very valuable in that period.

According to US Census Bureau 2001, the median price-to-rent ratio for single unit rentals in 2000 was 10, so we calibrate the rent/value ratio α to .10.[22] We set the landlord's share of rent, net of commissions, s^k to .91. This implies landlords break even on average, as $r_m^k + \delta^k + \tau^k$ - mean appreciation = .091, so net rent equals the cost of holding a property. Given our parameters the (pre-tax, real) internal rate of return for investment property, for a 30-year holding period, including transaction costs, is 3.73%.

The annual mortality rate $(1-\rho_t)$ is calibrated to the 1998 life table for the total U.S. population (CDC 2001). We set the annual discount factor to β=0.95.

Finally, we turn to income taxes. We set State income tax to 3% of gross income above \$10k. The progressive federal income tax in our model uses the actual US bracket and rate structure from 1968 to 2019, including the standard deduction, and the personal and dependents exemptions, obtained from https://taxfoundation.org/data/federal-tax/.[23]

5.2 The House Price Process

We calibrate the real house price index P_t^H in equation (4) using the Case-Schiller (CS) index from 1968 to 2019, presented in Shiller (2019). We convert all nominal quantities to real 1999 dollars using the CPI in Shiller (2019), see Table A1. Thus we normalize $P_t^H = 1$ when t corresponds to 1999. (Note that the CS index is *not* size specific).

The normalized real CS index increases from 0.851 in 1968 to 1.386 in 2019, which implies an increase in real house prices of 1.0% annually.[24] However, there were substantial year-to-year fluctuations around that trend, as we see in Figure 1. Looking at annual real house price changes from 1968-2019, the mean annual change is 1.08%, the median is 0.84%, and the standard deviation is 4.9%.

We calibrate the baseline values of 1 through 5-bedroom houses, denoted $\{h^1, ..., h^5\}$ in equation (4), using the median values of 1 to 5-bedroom owner-occupied homes in the PSID in 1999. We obtain \$59.5k, \$70k, \$90k, \$120k and \$170k, respectively.[25]

[22] The OECD price/rent ratio index in 2000 (96.8) is close to its average from 1970 to 2000 (95.9), so it is a good year to choose for calibration. The price/rent ratio increased substantially from 2001 to 2007, then returned to normal. In 2020-2023 it has increased dramatically, to well above the 2006 peak.

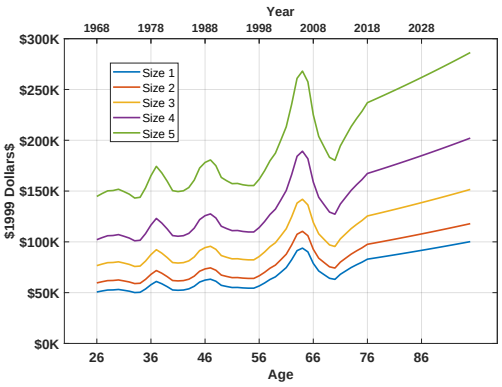
[23] From 2019 onward we assume the tax structure is constant.

[24] From 1968 to 2019, the nominal CS index increased 5.1% annually, while the CPI increased 4.1%.

[25] The mean values of one through 5 bedroom houses in the PSID in 1999 are \$68265, \$84214, \$109255, \$145077 and \$212004. Notice that the means exceed the medians. We have designed our model with the objective of fitting the medians. To fit the whole distribution of prices we would need to introduce quality and price heterogeneity, which would radically complicate the model.

Under our assumption of fixed *relative* prices for 1 through 5 bedroom houses,[26] we can use (4), combined with the Case-Schiller index, to obtain the values of 1 through 5 bedroom houses in any year – see Figure 1. The assumption of constant *relative* prices greatly simplifies the state space of our problem, as otherwise we would need a separate price process for each size house. It also allows us to overcome the data problem that the CS index is not size specific (and to our knowledge, no size-specific price index exists).

Figure 1: Real House Prices, 1 to 5 Bedroom Houses



While, actual house prices in the model follow the Case-Schiller index, agents in the model cannot anticipate how much prices will change each year. We assume they forecast prices based on a multinomial distribution, where the house price may decrease 5%, increase 1%, or increase 7%, with probabilities 1/3 each. This implies expected growth of 1.0%, which matches the annualized growth rate of the real Case-Schiller index from 1968 to 2019, and a standard deviation of 4.9%, which matches the standard deviation of annual growth rates. The simplifying assumption that agents forecast 3 possible price change scenarios makes it easier to take the expectation in (32), as we only have to integrate over three possibilities. We assume real house prices grow at a 1% rate from 2020 to 2037, consistent with the 1% rate from 1968-2019.

5.3 Household Income and Kids

We estimate the household income process in (22)-(24) using PSID data on households where the head is from the 1942 birth cohort. The PSID panel began as a sample of 4802 households with heads of all ages in 1968. The household heads in our cohort were age 26 in 1968, and they reach age 77 in 2019. To gain observations we take a 3-year window, so our cohort is age 25 to 27 in 1968. In 1968 to 1996 we observe roughly 300 households per year; see Appendix A, Table A1. The PSID sample was reduced 26% in 1997 due to budget cuts. This, along with mortality, causes our sample to fall into the 200 to 150 range in the subsequent years through 2019.

[26]The PSID does not ask number of bedrooms. It asks the total number of rooms excluding bathrooms. We classify a house with 3 or less rooms as 1-bedroom, 4 to 5 rooms as 2-bedroom, 6 to 7 rooms as 3-bedroom, 8 rooms as 4-bedroom, and 9+ rooms as 5-bedroom. One could say we model choice amongst houses of these sizes, using 1 to 5-bedroom as shorthand names for each size.

In our model, income from interest/dividends and rent is treated as endogenous, while income from all other sources (labor earnings, transfers, etc.) is treated as exogenous. To measure the exogenous household income we start with the PSID "total family money income" variable[27] and then subtract off asset and rental income.[28]

We estimate the income process separately for households where the education of the head is: less than High School, High School and College. The percentage of the cohort in each group is presented in Table 2. Note that 32% have less than a high school degree, which is exactly consistent with the HS graduation rate of 68% for the 1942 birth cohort reported in Heckman and LaFontaine (2010). We also construct the indicator K_{it} that equals 1 if the household had dependent children under age 18 at home, and 0 otherwise.

We begin by estimating the income model in (22) by random effects – see Table 2. As expected, households with a college educated head are predicted to have a much higher average income ($68k) than those with a high school ($43k) or less than high school educated head ($32k). But the standard deviation of the random effect is over .50 for all three groups, implying substantial within group heterogeneity in earnings capacity.

Table 2: Household Income and Kids Processes

Parameter	Description	$<$ HS	High School	College	Parameter	Description	Value(s.d)
	% of Cohort	32.200	50.700	17.100			
l_0	Constant	7.587(0.423)	8.341(0.289)	7.218(0.529)	a_0	Constant	-1.304(0.217)
l_1	Age	.138(0.029)	.104(0.020)	.188(0.035)	a_1	$(Age-25)$	0.007(0.036)
l_2	$Age^2/100$	-.224(0.063)	-.133(0.042)	-.283(0.074)	a_2	$(Age-25)^2/100$	-0.574(0.176)
l_3	$Age^3/1000$	.011(0.004)	.003(0.003)	.012(0.005)	a_3	$(Age-25)^3/1000$	0.089(0.024)
l_4	Age $>$ 65	.024(0.072)	-.020(0.048)	.030(0.070)	a_4	Kids(t-1)	5.156(.098)
l_5	Kids at Home	.103(0.023)	.052(0.018)	-.001(0.033)	a_5	Education=HS	-0.249(0.106)
	σ_{RE}	.572	.531	.551	a_6	Education=COL	-0.298(0.135)
	$\sigma_{Transitory}$	.437	.419	.429		Households	713
	Data mean	$32820	$44261	$68506		Observations	9308
	Sim. Data mean	$31073	$44055	$68896			
	Households	389	396	113			
	Observations	3229	5138	1735			

Based on these results, we decided to set the low, medium and high levels of the household specific intercept in equation (24) to (-σ_{RE},0,σ_{RE}), where σ_{RE} is the standard deviation of the random effects reported in Table 2. Within each education group, we assume 1/3 of the households fall into each intercept type, giving 9 income types.

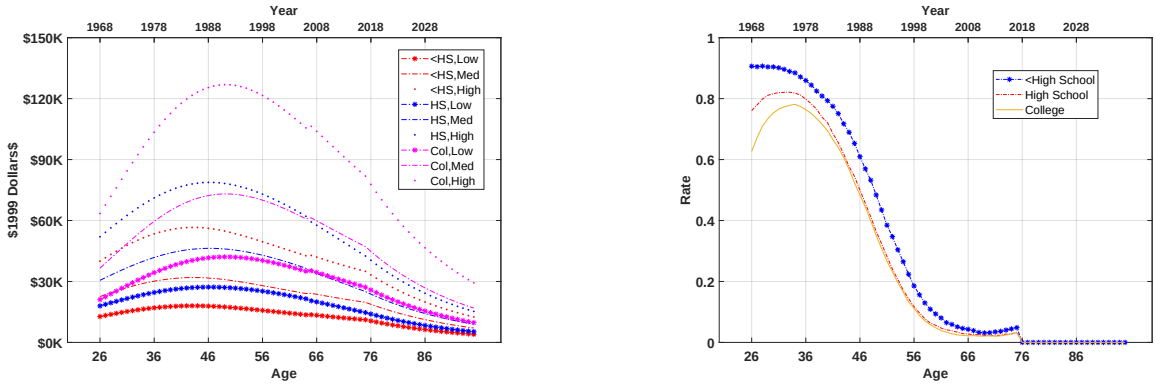
The standard deviation of the transitory error is over .40 for each group, but we suspect much of this is measurement error rather than true year-to-year variation in income, so we scale down the transitory standard deviation by half.[29] The simulated life-cycle income paths for each of our 9 types are shown in Figure 2, left panel.

[27] Total family Money Income is the sum of the following variables: Taxable Income of Head and Wife, Total Transfers of Head and Wife, Taxable Income of Others, Transfer Income of Others.

[28] We treat the lower 2.5% which is less than $5000, and the top 1% which is higher than $560k dollars, as outliers that are dropped from the estimation. Thus 357 of 10359 total observations are dropped.

[29] Keane and Wolpin (2001) estimate that much of transitory wage fluctuations are measurement errors.

Figure 2: Income and Kids Processes



(a) Income by types

(b) Probability of Dependent Kids at Home

We report estimates of the process for dependent children at home in the right panel of Table 2. After age 75 we assume the probability is zero. When we simulate data from this process we need to make an assumption about the probability that K(25)=1. We set this to .900, .725 and .586 for the three groups (taken from the PSID). Figure 2, right panel, shows how the probability of having kids at home varies by age.

5.4 Structurally Estimated Parameters

The model contains 21 utility function parameters that we estimate structurally via the method of simulated moments (MSM). We generate simulated data from the model, and compare it to the actual PSID data for the 1942 birth cohort. We seek parameters that minimize the sum of squared differences between numerous statistics from the simulated data and their PSID data counterparts. We present the estimates in Table 3, and discuss the statistics that we match in Section 5.4.2.

5.4.1 Structural Estimates

As we see in Table 3, all utility parameters are rather precisely estimated. The utility curvature parameters are very similar for housing services and non-housing consumption, implying there *would be* an approximately linear Engel curve for housing in a simple world without downpayment and PTI constraints, fixed costs, liquidity constraints, the dual nature of housing, and other complicating features of our model. Note that the estimates of γ and δ are both slightly above one, implying the utility function is slightly more concave than the log in both housing and non-housing consumption.

As expected, the service flow from housing, captured by $R(1)$ to $R(5)$, is increasing in the number of bedrooms. The estimates of μ imply the utility loss from renting rather than owning is 20% for a 1-bedroom, increasing to about 40% for a 4-bedroom. Owners can convert extra bedrooms into home offices, play rooms, etc., but renters have less flexibility to make modifications, so it makes sense they get less utility from extra bedrooms. We ruled out 5-bedroom apartments, as they are very rare.

Table 3: Structurally Estimated Utility Parameters

Parameter	Description	Estimate	(Std Err)
γ	CRRA, Non-housing Consumption	1.1136	(.0572)
δ	CRRA, Housing Consumption	1.1420	(.1614)
$R(1)$	Housing services, 1-bedroom house	1.3950	(.0739)
$R(2)$	Housing services, 2-bedroom house	2.1750	(.1072)
$R(3)$	Housing services, 3-bedroom house	2.4000	(.1458)
$R(4)$	Housing services, 4-bedroom house	3.0600	(.2112)
$R(5)$	Housing services, 5-bedroom house	3.4200	(.2609)
$\mu(1)$	Utility loss from renting, 1-bedroom	.8023	(.2035)
$\mu(2)$	Utility loss from renting, 2-bedroom	.7470	(.1544)
$\mu(3)$	Utility loss from renting, 3-bedroom	.6680	(.1565)
$\mu(4)$	Utility loss from renting, 4-bedroom	.6056	(.1717)
ψ_1	Taste for Housing, family with kids	.3786	(.0364)
ψ_0	Taste for Housing, family without kids	.3590	(.1092)
ψ_{0a}	Multiplier of ψ_0, Age < 45	.3996	(.0512)
Δ_s^o	Utility loss, Owner to renter	.0276	(.0063)
Δ_b^k	Utility loss, Become a landlord	.0274	(.0070)
Δ_s^k	Utility loss, Landlord to non-landlord	.0271	(.0071)
η	Strength of Bequest Motive	14.1271	(1.7876)
λ^c	Scale of Taste Shocks, Consumption choice	.0350	(.0088)
λ^h	Scale of Taste Shocks, housing services choice	.0672	(.0054)
θ_h	Age effect on scale, housing choice	.4449	(.2053)

The estimates of ψ imply *young* households (age<45) without kids get relatively little utility from housing. The Δ imply there is a utility loss from going from owner to renter, and there are utility losses from changing landlord status. The later may capture time costs of buying/selling rental property, finding tenants, learning to deal with tax issues, etc. Finally, $\theta_h<1$, so the taste shocks for housing options grow less important with age.

5.4.2 Data Used in the Structural Estimation

Here we describe the data used to obtain the MSM estimates. We collect household level data on home sizes and values, owner/renter status, landlord status, mortgage balances, consumption and financial assets from PSID data in survey years from 1968 to 2019. We study the cohort born in 1942, who reached age 26 in 1968 and 77 in 2019. To gain observations we consider a 3-year window of household heads aged 25 to 27 in 1968.

Statistics we match are: (1) the ownership rate, (2) the landlord rate, (3) the fraction of owners living in each size house, (4) the fraction of renters living in each size house, (5) the ownership rate by age, (6) transition rates between renter, owner and landlord status, (7) the distribution of house size conditional on kids and age of the household head, (8) the ownership and landlord rates and house size conditional on education, (9) financial assets by age, (10) net worth by age, (11) net worth conditional on renter/owner/landlord status, (12) home value, home loan value and financial assets conditional on owner/landlord status, (13) investment property value, and (14) housing and non-housing expenditure.

None of the endogenous variables we fit is available in all years from 1968-2019. One reason is the PSID became semi-annual after 1997. Furthermore, not every variable was

collected in every survey. A key advantage of MSM is we can construct moments based on simulated vs. actual data using only years when the actual data are available. Appendix Table A1 summarizes when each variable is available. We match 100 total moments.

Home ownership status, number of rooms, and house value are available in all waves of the PSID. We classify a household head as a landlord if they answer "own" to the own or rent question and "yes" to the "other real estate" question.[30] The other real estate question was only asked in 1984, 1989, 1994, and 1999-2019. So we only construct moments for landlord status in the model vs. data for those years. This is a good example of how MSM allows us to circumvent a missing variable problem.

We observe the owner-occupied home mortgage balance in 1969-72, 1976-81, 1983-97 and semi-annually from 1999-2019. We observe investment property equity, net worth, and financial assets in 1983, 1986, 1994, and semi-annually from 1999-2019. In 1999 the PSID introduced extensive expenditure data, so we observe housing expenditure, non-housing expenditure and total expenditure semi-annually from 1999-2019.[31]

We calculate household financial (or, more precisely, non-housing) assets in the PSID by summing the values of checking and savings accounts, stocks, vehicles, other assets, annuities, and the farm/business, minus credit card, student loan, medical, legal and family loan debt. Net worth is constructed as a sum of nine asset types: stocks, savings, equity in the primary home, equity in other real estate, the value of vehicles, the value of annuities and other assets, and equity in a farm/business, *minus* all other debts.[32]

We have designed our model with the goal of fitting median house values for each size house. To fit the whole distribution of prices, we would need to introduce heterogeneity in house quality within each size, which would radically complicate the model. To make the model and data consistent, we assign the median price for a j-bedroom house to all j-bedroom houses in the data. For example, we assign a value of \$90k to all 3-bedroom houses in 1999, the value we calibrate for all such houses in the model. Similarly, we adjust mortgage values to be consistent with our assumption that mortgage loans are always 80% of house value. Finally, we set financial assets of each household equal to its actual financial assets plus the difference between the original home equity in the data and the adjusted home equity in the model, thus leaving net worth unaffected.

Housing and non-housing expenditure data in the PSID are less complete and reliable than in the Consumer Expenditure Survey (CES). Hence we adjust the PSID data as follows: We compute the ratio of (population-wide) average housing (or nonhousing) expenditure in CES to that in the PSID. We then use this ratio to scale up or down the expenditure data in the PSID.

[30] We eliminate the rare cases where a household that rents also owns an investment property.
[31] We drop cases where the mortgage or investment property equity exceeds \$500000 in 1999 dollars.
[32] Observations in the top 3.5% of net worth (above \$1.75 million in 1999 dollars) are dropped.

6 Model Fit - 1942 Cohort Model

Here we describe the fit of the 1942-cohort model to the 1942 cohort data, focusing on a subset of the many statistics we fit in estimation – see Section 5.4.2. We only report those we consider most important: Table 4 shows the fit to the home ownership rate. The model fits the overall rate 64.9% almost exactly. It also fits the increase in the ownership rate from age 26 to 54 very well. A surprising aspect of the data is that the ownership rate continues to increase to about 78% at ages 55 to 77, while the model predicts it to plateau at about 72%. Finally, Table 4 also reports home ownership by education. The model fits the ownership rate of high school graduates quite accurately, but it slightly understates that of HS dropouts, while slightly overstating that of college graduates.

Table 4: Home Ownership Rates and Landlord Rates, Data vs. Model

Variable	Data	Model	Variable	Data	Model
Ownership Rate	.649	.649	**Landlord Rate**	.210	.215
Ownership by Age			**Landlord Rate by Age**		
Age 26-34	.457	.435	Age 26-34	-	.103
Age 35-44	.665	.678	Age 35-44	-	.237
Age 45-54	.684	.719	Age 45-54	.184	.223
Age 55-64	.770	.721	Age 55-64	.225	.238
Age 65-77	.785	.712	Age 65-77	.226	.194
Ownership by Education			**Landlord Rate by Education**		
Less than HS	.538	.456	Less than HS	.106	.091
High School	.677	.707	High School	.198	.220
College	.775	.840	College	.332	.432

Note: Landlord rate at 26-44 not observed in the data.

The model generates an owner-to-owner transition rate of 93.4% vs. 94% in the data, and a renter-to-owner rate of 15.5% vs. 11.1% in the data. So it slightly understates persistence in home ownership, while exaggerating the rate of renter to owner transitions. The two effects cancel out, so the overall ownership rate of 64.9% is accurate.

Table 4 also reports investment property ownership. The model fits the overall rate of 21% almost exactly. The landlord rate from ages 45 to 77 is fairly flat in both model and data. The PSID does not record investment property ownership at earlier ages, but the model predicts it rises substantially from ages 26 to 44. The model captures how landlord status increases with education, but it exaggerates the fraction of college landlords.

Table 5 shows the model fits the distribution of home sizes very accurately. The average house size of owner-occupiers is 3.21 bedrooms in both the model and data. The average size of rented apartments is 2.097 bedrooms in the model vs. 2.092 in the data.

Table 6 shows the distribution of home sizes by age. We match the distributions at ages 26-45 and 46-65 very accurately. Surprisingly, in the data the average house size increases slightly at at ages 66-77, while in the model it declines slightly. It is difficult for an economic model to rationalize why households don't downsize at older ages.

Table 5: Home Sizes, Data vs. Model

	All		Owners		Renters	
	Data	Model	Data	Model	Data	Model
1 Bedroom	.098	.105	.024	.029	.235	.235
2 Bedroom	.366	.364	.276	.270	.531	.527
3 Bedroom	.220	.219	.263	.262	.140	.144
4 Bedroom	.250	.251	.339	.342	.093	.094
5 Bedroom	.069	.062	.098	.097	.000	.000
Mean Size	2.833	2.801	3.211	3.21	2.092	2.097

Table 6: Homes Sizes by Age and Education, Data vs. Model

	26-45		**46-65**		**66-77**		**Less than HS**		**High School**		**College**	
	Data	**Model**	**Data**	**Model**	**Data**	**Model**	**Data**	**Model**	**Data**	**Model**	**Data**	**Model**
1 Bedroom	.100	.118	.096	.080	.120	.123	.123	.193	.088	.072	.094	.033
2 Bedroom	.397	.398	.332	.336	.265	.297	.447	.430	.373	.373	.208	.214
3 Bedroom	.233	.214	.202	.217	.207	.245	.226	.206	.241	.221	.160	.237
4 Bedroom	.238	.221	.257	.289	.290	.266	.169	.160	.240	.286	.393	.317
5 Bedroom	.032	.048	.112	.078	.118	.070	.036	.011	.058	.047	.146	.199
Mean Size	2.705	2.684	2.957	2.949	3.022	2.863	2.546	2.365	2.808	2.864	3.288	3.437

Notes: Data on all households (both renters and owners).

Table 6 also shows the distribution of home size by education. For households where the head has a high school education, which is the largest group (50.7%), the fit is very good. But the model slightly exaggerates the education gradient. For example, it slightly exaggerates how many <HS households live in one bedroom houses/apartments (19.3% vs. 12.3%) and it understates how many college households do so (3.3% vs. 9.4%).

Table 7: Financial Assets and Net Worth, Data vs. Model

Variables	Data	Baseline	Variables	Data	Baseline
Financial Assets by Age ($)			**One-home owners ($)**		
Overall	162,703	164,006	Home value	98,982	98,341
Age 42	80,666	76,125	Home loan	36,562	56,133
Age 47	127,448	122,238	Financial assets	171,063	166,082
Age 52, 57 to 64	178,146	172,455	Net worth	217,384	234,985
Age 65-77	192,863	194,791	**Landlords ($)**		
			Home value	136,450	142,137
Net Worth by Age ($)			Home loan	38,377	55,659
Overall	217,122	224,879	Investment equity	45,000	42,642
Age 42	118,516	100,582	Financial assets	262,601	253,128
Age 47	161,924	160,318	Net worth	408,827	396,009
Age 52, 57 to 64	235,100	241,590	**Renters ($)**		
Age 65-77	264,750	265,941	Financial assets	36,496	90,787

The left panel of Table 7 shows the fit to financial assets and net worth, overall and by age. We can only compare ages where the PSID reports these variables, as shown in the table. The fit is very good. The right panel reports financial variables separately for one-home owners, landlords, and renters (who have only financial assets). The model fits all financial variables very well for one-home owners and landlords. However, the model overstates mean financial assets of renters: $91k model vs. $36k data.[33]

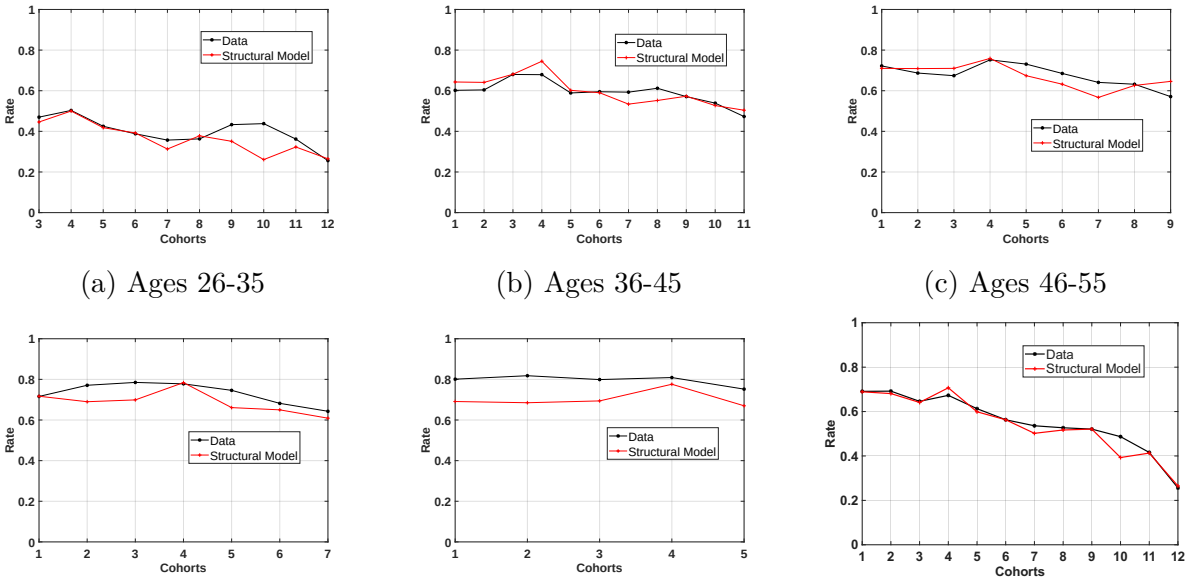
[33]This mean is taken over ages 42, 47, 52, and 57-77, so the model exaggerates assets of older renters. The model also exaggerates the number of older renters, Table 4. These problems are obviously linked.

We report numerous additional results in Appendix B1 and Appendix C4, including graphs of itemization, ownership, home size, assets and consumption by age.

6.1 External Validation: Fit to 1932 to 1987 Cohorts

The exogenous processes driving behavior in our model are income, kids, house prices, nominal interest rates and tax rules. To assess our model's out-of-sample fit, we plug in these processes for the 1932, 1937, ..., 1987 birth cohorts, and simulate ownership out-of-sample. Structural parameters in Tables 1 and 3 are of course held fixed. The procedure is described in detail in Keane and Liu 2025, and results are shown in Figure 3.

Figure 3: Ownership Rate Across Cohorts and Age Groups: Data vs. Model



(a) Ages 26-35 (b) Ages 36-45 (c) Ages 46-55

(d) Ages 56-65 (e) Ages 66-77 (f) All Observed Ages

Notes. Cohorts 1 to 12 correspond to the birth cohorts of 1932, 1937, 1942, 1947, 1952, 1957, 1962, 1967, 1972, 1977, 1982 and 1987. We use PSID data for a three-year window around each birth year.

Panels (a)-(e) show the ownership rate conditional on age trended down over cohorts. For instance, in the 26-35 age group, the ownership rate drops from 47.0% in the 1942 cohort to only 25.6% in the 1987 cohort. Our model captures this drop very accurately.

We fail to predict the brief rebound in ownership at young ages in cohorts 9 and 10. Chambers et al. 2009a show this was due to looser credit conditions in 1995 to 2006, when these cohorts were young. We do not model this, so it is no surprise we miss it.

Panel (f) shows the overall ownership rate for each cohort, averaged over all observed ages in the PSID. Our model fits the downward trend in ownership rates very accurately.[34] In Keane and Liu 2025 we show it predicts the overall drop from cohort 1 to 12 more accurately than a reduced-form logit designed exclusively to fit ownership rates, using

[34]The decline in ownership in Panel (f) occurs for two reasons: The ownership rate *conditional on age* is indeed trending down, as we saw in panels (a)-(e). But in addition, more recent cohorts are not observed in the older age cells, where the ownership rate is highest.

the same exogenous processes. Furthermore, the reduced form cannot evaluate welfare.

Overall, the structural model performs well in these external validity checks. Although our model simplifies reality in many ways, it still seems to capture the main factors driving changes in ownership across time/cohorts. These results give us added confidence in using the structural model to conduct counterfactuals where we change tax rules and other exogenous variables facing households.

7 Results – 1942 Cohort Model

Here we present simulation results for the 1942 birth cohort model, including scenarios where they face different tax rules. These simulations assess how the behavior of the 1942 cohort would have changed if they faced different constraints. To allay concerns the results are special to the 1942 cohort, we also present stationary model results in Section 8.

7.1 Heterogeneity in Demand for Housing

In Table 8 we report how demand for housing differs across the nine household types in the model, who differ by education and latent skill. We sort the types by ascending order of average income. Average home size is monotonically increasing with income, as we would expect. For example, type 6 (<HS, High) has income 23.7% higher than type 5 (HS, Med), and their average home size is greater by 12.3% (3.232 bedrooms vs. 2.876 bedrooms). This implies an income elasticity of demand of roughly .52. If we compare the richest two types we obtain an elasticity of .23, and if we compare the poorest two types we obtain .64. Thus, the income elasticity of demand is declining with income.

Table 8: Demand for Housing by Household Type

Type	Education	Skill	Income	Ownership	Home size	
				Rate	All	Homeowners
1	<HS,	Low	16300	.001	1.547	1
2	HS	Low	24258	.405	2.033	1.916
3	<HS	Med	28803	.484	2.315	2.337
4	Col	Low	36313	.639	2.668	2.829
5	HS	Med	41271	.768	2.876	2.985
6	<HS	High	51064	.880	3.232	3.319
7	Col	Med	62954	.897	3.443	3.554
8	HS	High	70186	.945	3.678	3.745
9	Col	High	109072	.974	4.155	4.199

The ownership rate is essentially zero for the poorest type (<HS, Low), as they are unable to afford the downpayment or pass the PTI test. But the second poorest type (HS, Low) has a much higher ownership rate of 40.5%. It is important to remember that owning is cheaper than renting due to tax advantages, and owning delivers greater utility for the same home size due to the rental utility discount μ. Hence, even poor households will choose to own if they can afford it. The ownership rate is monotonically increasing with income. But it increases with income at a rapidly decreasing rate.

7.2 Income and Price Elasticities of Demand for Housing

In Appendix Tables B.2 to B.4 we report on partial equilibrium experiments designed to assess how demand for housing – as measured by average home size in the economy, including both owner-occupied houses and apartments – responds to exogenous changes in household income, the price of housing and income tax rates. Here we summarize the results: The long-run income elasticity of demand for housing is approximately .54 in the aggregate, and it is decreasing with income. The uncompensated long-run price elasticity of demand for housing is approximately .47, and it is also declining with income.

The ownership rate is far more sensitive to both income and price at low income levels. As we saw in Table 8 high income types have a very high probability of ownership, so changes in income or price mostly cause then to adjust their house size.

The ownership rate is not very sensitive to income tax rates, and the sensitivity of home size is quite modest. The reason these sensitivities are small is as follows: Reduced tax rates do have a positive income effect on demand, but this is partially offset by the fact that lower rates make the tax advantages of owner-occupied housing less valuable. Finally, we find the demand for investment property is highly responsive to both income and price (even at high income levels).

7.3 Policy Experiment 1: Tax Net Imputed Rental Income

7.3.1 Impacts on Ownership Rate and Demand for Housing

First we consider an experiment where we tax imputed rent. Imputed rent is the flow of services from an owner-occupied house, valued at the cost of renting those services on the rental market. Here the *net* imputed rent is included in household income and taxed. As with any other asset or business income, households can deduct the costs of earning the imputed rent, which are the mortgage interest, depreciation and state tax. So for a household with mortgage balance M and house value H, the net imputed rental income is $IR^{net} = \alpha H - r_m M - \delta^o H - \tau^o H$. This is added to income in equation (16) and taxed.

If the government wishes to treat owner-occupied housing symmetrically with other assets, creating a "level" tax system, then at the same time it taxes net imputed rent it should also remove the itemized deductions for mortgage interest and property taxes in (17). However, it is plausible that a policy maker would choose to leave these deductions in place for the same reason they exist now: to encourage ownership. We first consider an experiment where imputed rent is taxed but these incentives are left in place.

As we see in Table 9 column 2, taxing net imputed rent causes the ownership rate to drop from 64.9 to 59.0% in partial equilibrium, a 9.1% decline. The drop is greater for low income households. As we see in Appendix B5 Table B4, for households where the head has less than HS education, the ownership rate drops from 45.6 to 40.2%, an 11.8% decline. For households where the head has College education the drop is only 4.3%.

Table 9: Experiments: Tax on Net Imputed Rental Income

	Baseline (1)	Partial Equilibrium (2)	Revenue Neutral (3)	Equilibrium Price (4)
Ownership Rate	0.649	0.590	0.596	0.600
Average Home Sizes				
All People	2.801	2.759	2.770	2.781
Owners	3.210	3.221	3.222	3.231
Renters	2.097	2.131	2.139	2.144
Ownership Rate by Age				
Age 26-35	0.435	0.413	0.419	0.423
Age 36-45	0.678	0.629	0.631	0.634
Age 46-55	0.719	0.643	0.651	0.653
Age 56-65	0.721	0.631	0.642	0.647
Age 66-77	0.712	0.631	0.643	0.648
Landlord Rate	0.215	0.203	0.205	0.207

Notes: (1) Baseline model, (2) Tax net imputed rent from owner-occupied housing, (3) Same as 2 but reduce income tax rates by 9.15% to achieve revenue neutrality, (4) Same as 3 but reduce house price by 0.714% to equate supply and demand.

We report detailed results by household type in Appendix B5 Table B5. As we see there, the ownership rate of the wealthiest households is little affected: For type 9s it only drops from 97.4 to 97.1%, and their average house size only drops from 4.155 to 4.132 bedrooms. In contrast, for type 5s (HS, Med), who sit near the middle of the income distribution, the ownership rate drops from 76.8 to 69.5%, a 9.5% decline, and their average house size drops from 2.985 to 2.911 bedrooms, a 2.5% drop. For low income households effects are even greater: The ownership rate of type 3s (<HS, Med) drops from 48.4 to 36.6%, and for type 2s (HS, Low) it drops from 40.5 to 28.0%.[35]

Taxing imputed rent raises substantial revenue, so in a revenue neutral simulation we can cut income tax rates by 9.15%. The revenue neutral results are shown in Table 9 column 3. The tax cut only leads to a slight rebound in the ownership rate, from 59.0% to 59.6%. This is consistent with our finding in Appendix B4 Table B1 that tax cuts of a similar magnitude (10%) have very little effect on demand for owner-occupied housing.

As we also see in Table 9 column 3, in a revenue neutral simulation taxing imputed rent causes a small 1.1% drop in average home size over all households, from 2.801 to 2.770 bedrooms. It mostly shifts demand away from owner-occupied housing towards rental housing – leading to only a small drop in overall demand for housing in the economy.

The drop in demand for housing will cause a drop in the price of housing in equilibrium (unless supply is infinitely elastic in the long run). As we explained in Section 3.4, we close the model by assuming an iso-elastic supply of housing, exactly as in Poterba (1984),

[35]Interestingly, as we see in Table 9, the average owner-occupied home size actually increases slightly from 3.21 to 3.22. This is due to a compositional effect whereby those who own relatively small houses in the baseline (i.e., the lower income households) are most affected by the policy.

Floetotto et al. (2016), Sommer and Sullivan (2018). This allows us to calculate the new equilibrium price in our counterfactual. Poterba (1984) and Sommer and Sullivan (2018) obtain elasticities of 1.0 and 0.9, respectively. We consider a similar value of 1.0. Given this value, we calculate that in the new equilibrium the price of housing drops by 0.714%.

An important caveat is this is a steady state analysis where all households are born into a world with taxation of imputed rent. Hence, we do not consider costs of converting an existing housing stock to the new demand patterns, such as converting some owner-occupied housing to rental property.

Table 9 column 4 shows results for the new equilibrium. The ownership rate is 60%. The average house size over both owners and renters is 2.781, which is 0.714% less than in the baseline. Of course, given unit-elastic supply, the drops in price and aggregate supply/demand are equal. A notable aspect of the new equilibrium is that the ownership rate of young households is only slightly lower than in the baseline (e.g., a 1.2pp drop at ages 26-35). But the ownership rate of older households drops substantially (e.g., a 6.4pp drops at ages 66-77). As the mortgage balance trends to fall with age, most net imputed rent flows to older households, and it these who largely pay the tax.

7.3.2 Welfare Impact of Taxing Net Imputed Rent

The failure to tax imputed rent creates an economic distortion, as income generated by financial assets is taxed, while the implicit rental income generated by owner-occupied housing is not. A renter is taxed on all his/her income from financial assets, but can avoid tax by shifting his/her wealth into housing. This creates two distortions: (i) there is over-consumption of owner-occupied housing, relative to rental housing and non-housing consumption, and (ii) there over-investment in housing relative to financial assets.

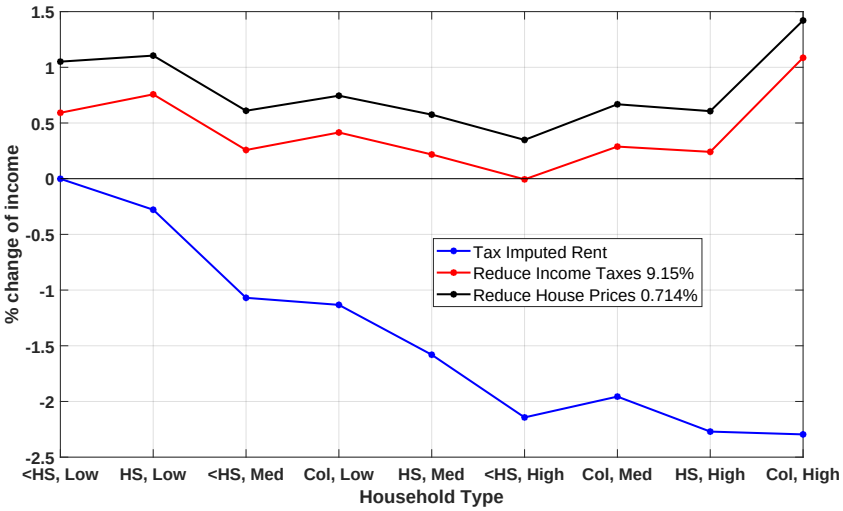
Figure 4 plots changes in the expected present value of lifetime utility viewed from households' initial state at age 25.[36] We convert this into equivalent changes in permanent income. The blue line in Figure 3 shows the partial-equilibrium impact of taxing imputed rent, leaving income tax rates and house prices unchanged. Note that the type 1s are unaffected as they almost never own a house. At the other end of the spectrum, type 8s and 9s experience welfare losses equivalent to about 2.3% of lifetime income.

However, a tax on imputed rent raises enough revenue to finance a 9.15% cut in income tax rates. In a revenue neutral simulation, shown by the red line in Figure 4, every type is better off, except for type 6 whose utility is unchanged. The gains for types 1s and 2s are 0.59% and 0.76% of lifetime income. The largest gain is 1.09% of lifetime income for type 9s. The average gain for all types is 0.43% of lifetime income.

Furthermore, recall that the price of housing drops 0.714% in equilibrium. The black

[36] We could equivalently call this the state at the start of age 26, prior to making any decisions. In the initial state households have no housing assets and no financial assets.

Figure 4: Welfare Impacts: Tax on Net Imputed Rent



line in Figure 4 factors in this additional benefit. Now taxing net imputed rent makes *every* type better off ex ante, including type 6, whose welfare gain is equivalent to 0.35% of lifetime income. The average gain over all types is 0.79% of lifetime income. Thus, the taxation of imputed rent is ex ante Pareto improving, as it eliminates distortions. (Note: The red and black lines bracket the cases of unit and infinitely elastic supply).

We also ran an experiment where we *both* tax net imputed rent and *also* eliminate the itemized deductions for mortgage interest and property taxes (Of course, they are still deducted from imputed rent to obtain *net* imputed rent). This creates a level tax system. In equilibrium this allows a 13% tax cut and leads to a 2.2% reduction in house prices. The ownership rate drops from 64.9% to 59.7%, with drops concentrated among low and middle-income households. All types are better off, especially low income households, so we get a Pareto improvement. The average welfare gain is equivalent to 1.4% of lifetime income, which is almost twice the 0.79% average gain that we found when we only tax imputed rent but leave MID in place.

Several caveats are notable: First, this is a steady state analysis with all households born into a world with taxation of imputed rent. If this occurred in real time, households that already had substantial home equity could be worse off. To avoid this, a tax on imputed rent could be grandfathered in. Second, in our model agents start at age 26 with no assets. An agent with inherited housing assets could be worse off. Third, taxing imputed rent reduces the ownership rate by 4.9 pp in the new equilibrium, with large effects for low-income types. The key justification for tax preferences is that ownership may create positive externalities. These may justify the policy *if they exist*. On the other hand, our model ignores other benefits of reducing income tax rates, such as increased labor supply and human capital accumulation, see Keane and Wasi (2016). Finally, there is the difficult practical problem of measuring the imputed rent so it can be taxed.

7.4 Experiment 2: Eliminate Mortgage Interest Deduction

Next we consider an experiment where we eliminate the MID. Table 10 column 2 shows the partial equilibrium results, holding income tax rates and house prices fixed. The ownership rate drops from 64.9% to 63.5%, and the average owner-occupied house size drops from 3.210 bedrooms to 3.104 bedrooms, a 3.3% decline.

Table 10: Experiment: Remove Mortgage Interest Deduction (MID)

	Baseline (1)	Remove MID (2)	Revenue Neutral (3)	Equilibrium Price (4)
Ownership Rate	0.649	0.635	0.636	0.643
Average Home Sizes				
All People	2.801	2.725	2.733	2.754
Owners	3.210	3.104	3.112	3.128
Renters	2.097	2.107	2.112	2.122
Ownership Rate by Age				
Age 26-35	0.435	0.426	0.429	0.439
Age 36-45	0.678	0.659	0.658	0.666
Age 46-55	0.719	0.704	0.705	0.708
Age 56-65	0.721	0.712	0.713	0.722
Age 66-77	0.712	0.704	0.707	0.715
Landlord Rate	0.215	0.235	0.234	0.243

Notes: (1) Baseline model, (2) Remove mortgage interest deduction, (3) Same as 2 but reduce income tax rates by 4.70%, (4) Same as 3 but reduce house price by 1.662% to equate supply and demand (tax rate is reduced 4.74%).

Perhaps surprisingly, we see smaller proportional effects on both margins for wealthier households with college educated heads: As we see in Appendix B Table B6, the ownership rate drops by 2.4%, 2.3% and 1.3% for <HS, HS and college households, while causing average owner-occupied house size to drop by 4.1%, 3.3% and 2.8%, respectively. The MID tends to be larger in magnitude for higher income households, both because they face higher marginal rates and they tend to own more valuable houses. But on the other hand, as we saw in Section 7.2, both income and price elasticities of demand for housing are much greater for lower income households.

Appendix B Table B7 sheds more light on this issue: Eliminating MID has a negligible effect on ownership rates of high income households, types 6 through 9. But it does cause them to buy smaller houses.[37] On the other hand, eliminating the MID causes noticeable declines in the ownership rate for the low and middle income households in types 2 through 5. For them, the ownership rate drops by 2.4, 3.2, 3.1 and 2.7 points, which are 5.9%, 6.6%, 4.9% and 3.5% declines, respectively. Thus, the MID played a role in making home ownership more affordable for low to middle income households, but for higher income households its only role was to encourage larger house sizes.

[37] Average owner-occupied house size to drops by 5.6%, 4.7%, 4.2% and 2.2% for types 6 through 9, respectively. The absolute drop is about 0.17 bedrooms for types 6 to 8, and 0.10 bedrooms for type 9.

Eliminating the MID raises substantial revenue, so we can reduce all marginal income tax rates by 4.7% in a revenue neutral simulation. We report these results in column 3 of Table 10. As we saw in Section 7.2, a tax cut has little effect on demand for housing, so it is not surprising that columns 2 and 3 are little different. The overall average home size drops from 2.801 in the baseline to 2.733 in the revenue neutral experiment. Thus, eliminating the MID reduces the overall demand for housing by 2.4% with price fixed.

The drop in demand causes both the price and total quantity of housing to fall 1.66% in equilibrium, given our unit elastic supply assumption. We report these results in column 4 of Table 10. Factoring in the price drop, the ownership rate only drops 0.6 pp

Figure 5: Welfare Impacts: Remove Mortgage Interest Deduction

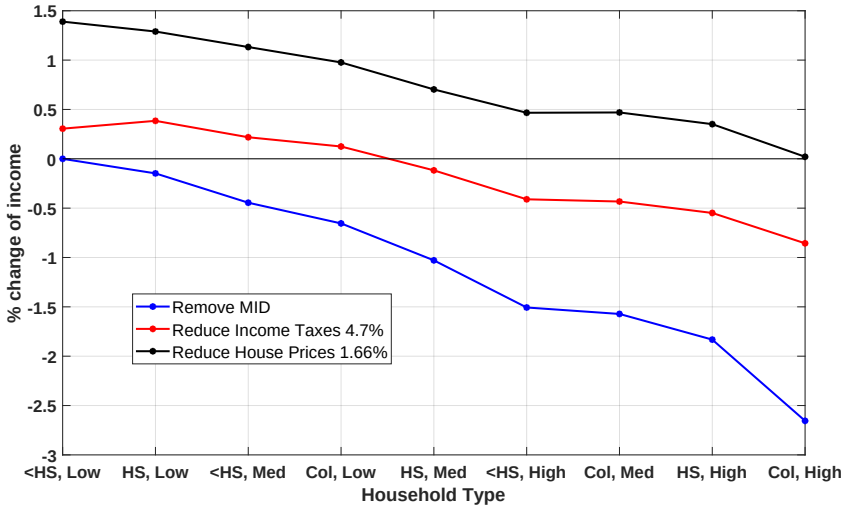


Figure 5 shows welfare impacts. Removing MID with taxes and prices fixed (blue line) has no effect on type 1s, who almost never own. The impact is increasing with income, and for type 9s we have a loss equivalent to 2.7% of lifetime income.[38] When we also reduce income tax rates by 4.7% in the revenue neutral simulation (red line), types 1 through 4 are better off but types 5 through 9 are worse off than in the baseline. Thus, there are winners and losers. In contrast to a tax on imputed rent, we do not obtain a Pareto improvement in a fixed price experiment. The MID transfers wealth from poorer to wealthier households, so eliminating it makes the wealthy households worse off.

Finally, given unit elastic supply, the equilibrium price of housing falls 1.66%. Factoring in the price drop, all types are better off, as shown by the black line in Figure 5, so we do have a Pareto improvement. The average welfare gain is equivalent to 0.76% of lifetime income, with the gains heavily concentrated on low and middle-income households. (Note: The red and black lines bracket the cases of unit and infinitely elastic supply).

[38]The estimated tax expenditure on the mortgage interest subsidy for homeowners was $64 billion in 1999. Census 2000 counted 69.8 million owner-occupied housing units, or about two-thirds of the 105.5 million occupied housing units in the United States, Source: https://www.census.gov/library/publications/2003/dec/c2kbr-27.html. So the average annual tax expenditure per homeowner was about 916 dollars, and the average tax expenditure per household was about 600 dollars.

7.5 Experiment 3: Convert the MID into a Refundable Credit

In Section 7.4 we saw the MID is regressive. It made ownership more affordable for low to middle-income households, but for high-income households it only encouraged larger house sizes. The Domenici-Rivlin, Bowles-Simpson and Mack-Breaux commissions all recommended converting the MID into a flat-rate tax credit that does not depend on ones' marginal tax rate, as have several authors and think tanks ranging across the political spectrum (see, Dreier 1997, Green and Vandell 1999, Hanson et al. 2014, Lu and Toder 2016, Drukker 2021, Waters et al. 2023). But the policy has never been formally evaluated in a dynamic model. Here we evaluate a fully refundable credit that is a flat percentage of mortgage interest.

To replace the MID with a flat-rate credit we must first decide the rate. In our model a flat-rate 24.6% refundable credit is revenue neutral. Several analyses in static models find converting MID to a smaller 15% credit would raise substantial revenue, see Lu and Toder 2016. Under our flat-rate 24.6% credit, households facing a marginal tax rate lower (higher) than 24.6% will receive a larger (smaller) mortgage interest deduction.

Table 11 column 2 shows the impact of replacing MID with the 24.6% refundable mortgage interest credit, holding price of housing fixed. The ownership rate increases substantially, by 3.3 points from 64.9 to 68.2%, a 5.1% increase. The proportional effect is greatest for younger households: In the 26-35 age range the ownership rate increases 3.3 points from 43.5 to 46.8%, a 7.6% increase. Effects are also greater for lower education households: As we see in Appendix B5.3 Table B8, the increases are 2.6pp (5.7%) for the <HS type, 4.7pp (6.6%) for the HS type – but only 0.9pp (1.1%) for the college type.

Table 11: Experiments: Refundable Mortgage Interest Tax Credit

		Mortgage Credit - 24.6%		Choose MID or Credit	
	Baseline	Rev. Neutral	Equilibrium	Rev. Neutral	Equilibrium
	(1)	(2)	(3)	(4)	(5)
Ownership Rate	0.649	0.682	0.687	0.684	0.685
Average Home Sizes					
All People	2.801	2.747	2.765	2.793	2.796
Owners	3.210	3.076	3.092	3.146	3.147
Renters	2.097	2.085	2.092	2.081	2.082
Ownership Rate by Age					
Age 26-35	0.435	0.468	0.477	0.466	0.467
Age 36-45	0.678	0.704	0.707	0.704	0.705
Age 46-55	0.719	0.750	0.752	0.754	0.755
Age 56-65	0.721	0.771	0.775	0.775	0.776
Age 66-77	0.712	0.763	0.772	0.765	0.767
Landlord Rate	0.215	0.232	0.238	0.213	0.214

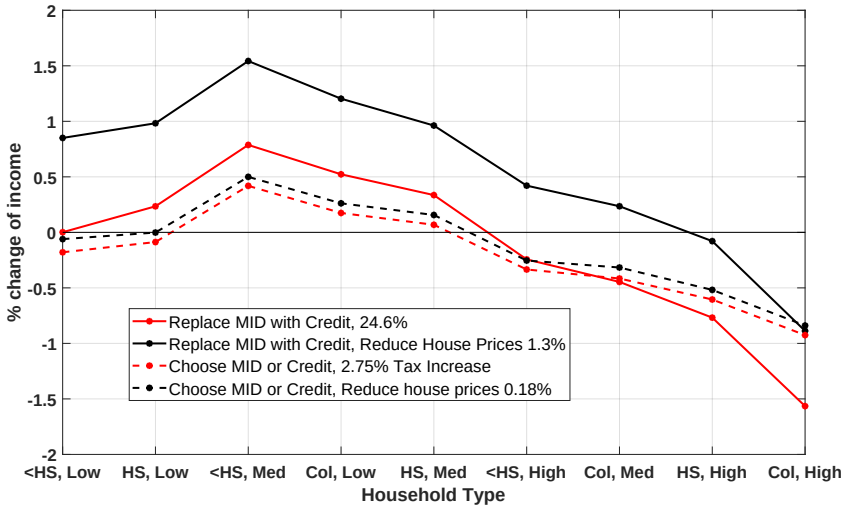
Notes: (1) Baseline model, (2) Partial equilibrium experiment: Remove the MID and replace with a fully refundable 24.6% mortgage interest credit (revenue neutral), (3) Same as 2 but price drops 1.3%, (4) Choice of MID or Credit, increase income tax rates 2.75% to achieve revenue neutrality, (5) Same as 4 but price is reduced 0.18% to equate demand and supply.

The refundable credit is effective at making ownership more affordable for low income types. As we see in Appendix B5.3 Table B9, the large positive effects on ownership are heavily concentrated on the low income types 2 and 3. The type 2 ownership rate increases from 40.5 to 53.9%, and that of type 3s increases from 48.4 to 55.0%. The ownership rate of the high income types 5 through 9 is little affected.

Replacing MID with a refundable credit reduces the overall demand for housing in the economy, as the average house size drops from 2.801 to 2.747 bedrooms, a 1.9% decline. This is driven by relatively wealthy households shifting to smaller houses, as their after-tax interest payments increase.[39] The fraction of households that hold investment property increases by 1.7pp as agents seek to maintain exposure to housing as an asset class.

The drop in demand causes the price of housing to drop by 1.3% in equilibrium, given our unit elastic supply assumption. These results are reported in Table 11 column 3. The ownership rate increases further to 68.7%, which is 3.8pp (5.5%) above the baseline. And as we see in Appendix B5 Table B9, the increases in ownership are concentrated among low-income types types 2 to 4, while house size drops for high-incomes types 6 to 9.

Figure 6: Welfare Impacts: Refundable Tax Credit



Next we examine welfare impacts: The red line in Figure 6 shows effects of replacing MID with a credit, with prices fixed. Welfare increases substantially for types 2 to 5, but falls for types 6 to 9. So there are winners and losers, but, as expected, a refundable credit is more progressive than the MID. The welfare impacts in equilibrium, given the 1.3% drop in the price of housing, are shown by the solid black line in Figure 6. The average welfare gain is equivalent to 0.58% of lifetime income. Types 1 through 7 are all better off, type 8 is very slightly worse off, and type 9 is worse off by 0.9% of lifetime income. (Note: The red and black lines in Figure 6 bracket welfare changes in the unit and infinitely elastic supply cases.)

[39] As we see in Appendix B5.3 Table B9, average owner-occupied home size drops by .07 bedrooms for type 5, .14 for type 6, .14 for type 7, .12 for type 8 and .07 for type 9.

Thus, we find that taxation of net imputed rent and removing MID both give Pareto improvements, while replacing MID with a credit does not. But the refundable credit is the only policy that substantially increases home ownership rates, especially for low and middle-income households and young households. These may be important policy goals in themselves. Furthermore, the high income households receive disproportionate benefits from tax preferences in the baseline system, so a policy that transfers welfare from type 9s to types 1 through 7 may in fact be desirable.

7.5.1 Choice of MID or Credit

An alternative policy designed to reduce losses for high income types is to give households a *choice* between the MID and the 24.6% refundable credit. High income households can continue to choose the MID if it offers a greater tax break than the credit. To make this policy revenue neutral we need to increase income tax rates by 2.75%. As we see in Table 11 column 4, this combined policy increases the ownership rate to 68.4% and reduces average house size very slightly to 2.793, an 0.3% drop. So in the new equilibrium, shown in column 5, price drops by only 0.18%.

The dotted black line in Figure 6 shows the impacts of this policy in equilibrium, given the 2.7% tax increase and 0.18% price reduction. It is notable that type 1 and types 6-to-9 are all worse off. The average welfare loss is 0.12% of lifetime income, so this policy is clearly undesirable. Even type 9s are actually slightly worse off than in the experiment where we simply replace MID with a credit. The reasons the "choose MID or credit" policy does so poorly are (i) a 2.75% tax increase is required to finance it, and (ii) it does not generate a significant drop in the equilibrium house price, as it does not remove the incentive for high income households to buy larger houses.

8 Stationary Model Analysis

Are the results in Sections 7.3-7.5 specific to the environment faced by the 1942 birth cohort? Or would similar results hold in different environments? The 1942 cohort faced a number of special conditions: High nominal interest rates in their 30s and 40s, making MID very valuable, and a run up in house prices in their 60s. The standard deduction increased over their lives, making itemization less attractive. Fortunately, given our structural estimates of preferences, we can predict how households would behave if they faced any counterfactual path of taxes, prices and interest rates over their lives.

Here, we take our structural estimates of preferences from Table 3, along with our estimated income/kids processes, and plug them into a stationary model where nominal interest rates, prices and the tax structure are fixed at year 2000 values. We could pick any year, but we choose 2000 as house prices, rent, interest rates and the standard deduction in that year were around average for our sample period.

We focus on a stationary model as the prior papers discussed in Section 2 calibrated stationary OLG models. This includes Gervais (2002), Chambers et al. (2009a,b,c), Cho and Francis (2011), Floetotto et al. (2016) and Sommer and Sullivan (2018). Their models have a fixed tax structure over time, constant house prices and interest rates, and a fixed income process across cohorts. In a stationary environment, our life-cycle model is isomorphic to an OLG model where all cohorts have identical income/kids processes.

Table 12 reports ownership rates in the stationary model. The average rate of the cohort hardly changes. However, the age profile of ownership steepens substantially. At ages 26-34 it drops from 43.5% in the 42-cohort model to 30.9% in the stationary model. In contrast, at ages 55-64 the ownership rate increases from 72.1% to 84.4%.

Table 12: Home Ownership Rates, 1942-Cohort Model vs. Stationary Model

Variable	Data	1942-Cohort	Stationary
Ownership Rate	0.649	0.649	0.643
Ownership by Age			
Age 26-34	0.457	0.435	0.309
Age 35-44	0.665	0.678	0.620
Age 45-54	0.684	0.719	0.750
Age 55-64	0.770	0.721	0.842
Age 65-77	0.785	0.712	0.879

The main reason for the pivot in the ownership profile is that the real price of housing is fixed at the year 2000 (age 58) level in the stationary model. This is near the midpoint of households' 70 year life-cycle. So compared to the 1942-cohort, the real price of housing is higher for the first half of the life-cycle, at ages 26 to 57 (corresponding to years 1968-1999), and lower for the second half, at ages 59 to 95 (years 2001-2037).

Furthermore, in the 1942-cohort model MID is especially valuable to relatively young households, due the high nominal interest rates (in excess of 10%) that prevailed from 1979 (age 37) to 1990 (age 48). This created an incentive to buy at young ages, which is eliminated in the stationary model as we fix the nominal interest rate at the 2000 level.

Households are effectively poorer (in present value terms) in the stationary model for three main reasons: First, the higher price of housing at young ages reduces lifetime wealth, as younger ages matter more for the present value (PV) of lifetime wealth. Households arrive at age 58 with less savings and lower net worth, and lower housing costs at older ages do not compensate for this. Second, with house price fixed, households don't reap the benefit of house price appreciation. Third, average tax rates were (modestly) above average under the 2000 tax code, compared to other years in the sample. The fact that households are poorer also causes then to delay home purchases until older ages.

In Appendix C we discuss many features of the stationary model, and how they differ from the 1942-cohort model. Comparison of Figures C1 and B1 reveals the average value of MID to homeowners is much more stable over the life-cycle in the stationary model.

We now use the stationary model to perform the same experiments as we performed in the 1942-cohort model. These results are discussed in detail in Appendix D. The main results are summarized in Table 13. The key finding is that eliminating MID, or, alternatively, replacing MID with a flat rate credit, both lead to larger welfare gains than in the 1942-cohort model. The average welfare gains from these two policies are equivalent to 1.30% and 1.14% of lifetime income, compared to 0.75% and 0.58% in the 1942-cohort model. Furthermore, the flat rate credit now generates a Pareto improvement, whereas in the 1942-cohort model it made types 8 and 9 worse off.

Table 13: Summary Results - Stationary Model

Experiments	Ownership Rate	Home Size	Tax Rate Change %	Price Change %	Welfare Gain	Types Worse Off
Stationary Model Baseline	0.643	2.608	-	-	-	-
Tax Net Imputed Rent	0.586	2.597	-8.30	-0.40	0.820	None
Remove MID	0.640	2.563	-3.60	-1.70	1.301	None
Flat Rate Credit	0.668	2.570	0.00	-1.45	1.143	None
Choice MID or Credit	0.674	2.596	1.75	-0.50	0.320	8,9

Eliminating MID generates greater welfare gains in the stationary model for a simple reason: While MID is distortionary, it does have a positive re-distributional aspect in the 1942-cohort model: It was most valuable when households were young, due to the high interest rates in the 1979-1990 period, so it generated an income transfer to relatively young and liquidity constrained households. This positive aspect of the MID is no longer relevant in the stationary model, where MID operates the reverse way: It transfers income to the relatively wealthy older households who have a much higher ownership rate.

9 Conclusions

We have estimated a life-cycle consumption/savings model, including decisions about home ownership and investment property. We extend prior work in several dimensions: By including investment property we allow investment demand for housing to exceed the consumption demand. A model that fails to account for this may exaggerate consumption demand for housing. We also include house price uncertainty and risky capital gains. We model the payment-to-income (PTI) constraints on mortgage loan qualification, which prior work has not considered. We model changes in the tax structure from 1968 to 2019 in detail, and agents in our model choose between itemized and standard deductions. And we include key life-cycle features: heterogeneous age-earnings profiles and household demand for housing that varies with age and presence of children.

Our model allows us to assess impacts of favorable tax treatment of owner-occupied housing on ownership, home size, investment property, financial assets and consumption. We estimate the model on PSID data for the 1942 birth cohort, and use the structural estimates to conduct experiments in both the 1942-cohort model and a stationary model where agents face tax rules, house prices, interest rates and rent prevailing in 2000.

We highlight three main findings: First, favorable tax treatment of housing creates inefficiencies that we quantify. In the 1942-cohort model, taxing net imputed rent on owner-occupied housing would raise enough revenue to finance a 9.15% cut in income tax rates and lead to a 0.71% drop in house prices in equilibrium. The ownership rate falls from 64.9% to 60.0%, with declines concentrated among low- and middle-income and older households. But overall housing demand falls only slightly, as demand shifts from owner-occupied homes to rentals. All household types would be ex ante better off if born into such a world, yielding a Pareto improvement. The average welfare gain is equivalent to 0.79% of lifetime income.[40] Results in the stationary model are very similar.

Second, the mortgage interest deduction combined with progressive taxes encourages wealthy households to buy larger homes, with little effect on their tenure choices. Eliminating MID raises enough revenue to finance a 4.7% or 3.6% cut in income tax rates in the 1942-cohort and stationary models, respectively. Ownership rates decline very slightly, but high income households buy smaller homes, leading to a 1.7% drop in equilibrium house price in both models. All types of households are ex ante better off if born into a world without MID, giving a Pareto improvement. The average welfare gains are 0.76% and 1.30% of lifetime income in the 1942-cohort and stationary models, respectively.

The reason the gain from eliminating MID is greater in the stationary model is simple: In the 42-cohort model, MID transfers substantial wealth to younger households due to its high value in the 80s. This partially counteracts its other negative welfare effects.

Third, we find that a refundable mortgage interest credit, which provides payments even to households that do not itemize, substantially improves housing affordability for low- to middle-income households, without raising taxes or driving up house prices. In the stationary model MID can be replaced with a 18.5% flat-rate credit in a budget-neutral simulation. The ownership rate increases by 2.5 percentage points, but aggregate housing demand is reduced, as high-income households buy smaller homes, leading to a 1.45% price drop. The average welfare gain is 1.14% of lifetime income. All types are better off, giving a Pareto improvement, but the largest gains are for lower-income households. In the 42-cohort model the credit policy makes the richest households worse off, as they benefited greatly from MID in the 80s, and the average welfare gain is reduced to 0.58%.

Of the policies we analyze, only a refundable mortgage interest credit increases home ownership, especially for low and middle-income households and young households, while also improving welfare. The Domenici-Rivlin, Bowles-Simpson and Mack-Breaux commissions all recommended a shift to a credit policy, and our results support it. Ours is the first paper to simulate the impact of a refundable credit in a dynamic model.

[40] Our model fails to capture positive externalities from home ownership, which may still justify the non-taxation of imputed rent (Although the existence of such externalities is controversial). But our model also fails to capture the positive impact of income tax cuts on labor supply and human capital accumulation, which would be added benefits of taxing imputed rent and reducing income tax rates.

Our results on the impact of taxing imputed rent or eliminating MID on ownership are different from those in prior literature: Unlike Berkovec and Fullerton (1992), Chambers et al. (2009b) and Sommer and Sullivan (2018), we do not predict taxing imputed rent or eliminating the MID would actually *increase* ownership. For instance, our stationary model predicts these reforms would reduce the ownership rate by 5.7pp and 0.3pp in equilibrium.[41] But neither do we predict *very large* negative effects, as in Gervais (2002), Cho and Francis (2011) and Floetotto et al. (2016). Our results fall in between.

We conclude by noting a limitation of our analysis: Our experiments assess impacts on cohorts born into a new policy environment, so this is a long-run steady-state analysis. In the short run, older agents who already hold substantial housing assets when a policy is implemented may be made worse off by the policies we consider. (A potential solution is to grandfather in policies.) The advantage of the OLG models used by Gervais (2002), Chambers et al. (2009b), Cho and Francis (2011), Floetotto et al. (2016) and Sommer and Sullivan (2018) is they can, at least in principle, analyze the impact of policies that are implemented at a point in real time, when different cohorts are in different points of their life cycles, provided such a transition analysis is computationally feasible.[42] On the other hand, as we noted in the introduction, our approach has several advantages, such as: (i) making it feasible to model household decision making at a much more detailed level, (ii) allowing for changes in house prices and tax structure over time in estimation, which helps to identify price and income elasticities of demand, and (iii) fitting the model to detailed micro data rather than a small set of aggregate statistics.

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[41] We find these policies have small effects on overall demand for housing, as they shift demand from owner-occupied to rental property, so they do not have large equilibrium price effects in the long run.

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