ARC Centre of Excellence in Population Ageing Research

Working Paper 2024/24

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

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September 30, 2024

Abstract

We present a dynamic life-cycle model of demand for housing, including owner-occupied housing, investment property and liquid assets. Households face down-payment requirements and liquidity constraints, and a progressive tax system where owner-occupied housing is subsidized. The model replicates key facts about home ownership, financial assets, debt and consumption. Our model predicts that taxing imputed rent would raise enough revenue to fund a 9.15% income tax rate cut, and lead to substantial efficiency gains. We also find that replacing the mortgage interest deduction with a refundable 24.6% mortgage interest credit would increase the ownership rate by 5.9%. 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

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 from owner-occupied home sales are largely untaxed. To analyze the impact of these tax advantages, we present the first life-cycle model of demand for housing in which owner-occupied housing, investment property and financial assets are treated as separate asset classes. Using PSID data from 1968 to 2019, we estimate/calibrate the model to fit the behavior of 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. We use the model to simulate the impact of the favorable tax treatment of housing on demand for housing, and on consumer welfare.

*Keane: Carey Business School, Johns Hopkins University, Cepar, UNSW; Liu: Cepar, UNSW and Tongji 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).

We find favorable tax treatment of housing increased home ownership of low and middle income households, but at a substantial cost in economic efficiency. It leads to two distortions: (1) over consumption of owner-occupied housing and (2) over investment in owner-occupied housing relative to other assets. We simulate that taxing imputed rent, net of mortgage interest and other costs, would lead to an 9.15% reduction in income tax rates and an 0.7% drop in house prices in equilibrium. If the cohort were born into such a world, expected lifetime utility all types of households increases, giving a Pareto improvement. The average welfare gain is equal to 0.79% of permanent income.

Our simulations also show the mortgage interest deduction is a regressive policy, 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 a 4.7% reduction in tax rates and a 1.66% drop in house prices in equilibrium. The average welfare gain is equal to 0.76% of permanent income. All types are better off, so we again have a Pareto improvement, but the gains are much greater for low income households.

Converting MID into a refundable mortgage interest credit of 24.6% is revenue neutral, and reduces house price 1.3% in equilibrium. The ownership rate of low-income households increases, while high-income households buy smaller houses. The average welfare gain is 0.58% of permanent income, but the wealthiest households are worse off, while low and especially middle-income households are better off. Prior work has not simulated the impact of a refundable credit policy.

Our work is most closely related to the 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 the preferential tax treatment of owner-occupied housing in dynamic general equilibrium OLG models. In contrast, we estimate a life-cycle model for a single cohort. Both approaches have their advantages:

The advantage of our life-cycle approach is that we model individual household decision making, and the constraints facing individual households, in much greater detail: We can handle more assets classes (owner-occupied and investment property, each financed by separate mortgages, along with liquid assets), and treat the purchase of owner-occupied and rental property as separate decisions. We incorporate a richer structure of household heterogeneity, including life-cycle patterns of income and family composition. We also model the tax system in much greater detail than earlier papers, as we use the actual detailed tax parameters that existed annually from 1968-2019. And, most importantly, we fit the model in great detail to life-cycle profiles of property ownership and financial assets, which are heterogeneous across types of households, while the macro papers only match a small set of aggregate statistics.

For the 1942 cohort that we study, high nominal interest rates made the mortgage interest deduction very valuable in the 1970s and 80s, when they were in their 30s and

40s. After TRA 1986, the combination of falling nominal rates, reduced tax progressivity, and increases in standard, personal and child deductions started to make both mortgage interest and property tax deductions less valuable, and fewer people itemized.[1] Our model incorporates the decision to itemize, and captures the impact of these changes in tax rules and nominal interest rates on the mortgage interest deduction.

Tax preferences for housing have been justified on the grounds that home ownership generates positive externalities. But 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.

We find that eliminating the mortgage interest deduction reduces the ownership rate by 0.6pp, from 64.9% to 64.3%, in a balanced budget simulation where price adjusts. These reductions are concentrated among low to middle-income households. High income households respond primarily by reducing house size. In sharp contrast, replacing MID with a refundable mortgage interest deduction, which generates payments to households that do not itemize, would substantially improve housing affordability. The MID can be converted to 24.6% credit in a revenue neutral simulation. This causes the ownership rate to increase by 3.8pp (5.9%). These increases are concentrated among low and middle-income households and young households, while high income households are little affected.

2 Literature Review

Rosen (1985) surveys several classic papers that estimate the effect of taxes on demand for housing. Especially notable are Laidler (1969), Rosen (1979), Rosen and Rosen (1980), Hendershott and Schilling (1982) and King (1983). These papers focus on how taxes affect the user cost of housing. Under a "level" tax system, where the service flow from housing is taxed while costs of acquiring those services are tax 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.[2] 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. 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 7.2%.

[1] Nevertheless, Poterba and Sinai (2011) estimate tax expenditures on MID were $72.4 billion in 2003.

[2] This simple expression assumes the mortgage rate equals the opportunity cost of funds, and that depreciation and maintenance are proportional to house value, and it ignores price appreciation. Then the gross annual cost of renting a dollar's worth of housing capital is $i + \tau_p + \delta$. In a level tax system the service flow generated by the capital is taxed at rate τ, and all three costs of renting the capital are tax deductible at the same rate. Thus taxation reduces both the service flow and the cost of capital by τ%, so τ drops out of the after-tax user cost expression.

The typical paper in this literature regresses housing demand on the after-tax user cost and income, along with demographic controls, and relies on time-series and/or cross-section variation in user costs to identify the price elasticity of demand. The consensus finding is that the price elasticity of demand for owner-occupied housing is about 0.5 to 1.0, and that elimination of tax preferences would reduce the ownership rate by about 4 points, from the roughly 64% that prevailed in the US for most of the post-war period to about 60%. Effects on house size are estimated to be larger, in the range of 10% to 15%.

As Hendershott and Schilling (1982) note, after factoring in house price appreciation at rate q the user cost of housing is $(i + \tau_p)(1 - \tau) - q + \delta$. As mortgage interest is tax deductible while capital gains are untaxed, the i term is multiplied by $(1-\tau)$ but q is not. Hence, inflation that raises the nominal interest rate i and the house price appreciation rate q by the same amount lowers the user cost. Poterba (1984) analyzed the impact of inflation on demand for housing, while extending earlier work to include a supply side model, where the supply of housing is unit elastic. He shows how the impact of tax preferences on demand for housing is greatly amplified in an inflationary environment. For example, in an economy with equal 10% rates of inflation and house price appreciation, and a 25% tax rate, eliminating mortgage interest deductibility increases the user cost by 75% and reduces the long run housing stock by 29%. Taxing imputed rent increases the user cost by 33% and reduces the housing stock by 17%.

A limitation of these studies is that housing is treated analogously to other physical assets, allowing demand to be analyzed using standard neoclassical investment theory. This abstracts from several special features of housing. In particular, (i) housing is a lumpy asset whose purchase requires a substantial downpayment, (ii) buying and selling a house involve substantial transaction costs, (iii) housing has a dual nature as both an investment and consumption good. As Henderson and Ioannides (1983) note, the dual nature of housing may cause the desired level of housing investment to deviate from the desired level of housing services consumption. If the former exceeds the latter a home-owner may also choose to acquire investment/rental property. Conversely, if consumption demand exceeds investment demand a household may rent rather than own.

As Rosen (1985) notes, a challenge for these early studies is to explain why the ownership rate has been so stable at about 64% despite substantial changes in user costs over time.[3] For example, he notes that user cost was driven to zero in the high inflation environment of the 1970s, yet the ownership rate rose by only about one percentage point.

[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. As Chambers et al. (2009a) show, the increase in 1996-2005 can be largely explained by increased availability of low downpayment "combo" loans that attracted young households. The ownership rate increased from 48% to 64% from 1946 to 1965. Chambers et al. (2009a) show that this can be largely explained by the reduction in the typical downpayment requirement from 50% to 20%, and increase in the typical mortgage term to 30 years, due to the FHA policy of underwriting 30-year 20% down mortgages.

Conversely, Poterba (1992) documents substantial increases in user cost in the 1980s, but this did not substantially reduce ownership. Both authors note that the combination or downpayment requirements, rationing of mortgage loans, and costly adjustment make it difficult for ownership to adjust to changes in user costs in the short run. More recent work on demand for housing relies on models that make downpayment constraints and transactions costs explicit. We now turn to those studies.

Our work is most closely related to papers by Gervais (2002), Chambers et al. (2009b), Cho and Francis (2011), Floetotto et al. (2016) and Sommer and Sullivan (2018), that analyze the impact of the preferential tax treatment of owner-occupied housing in dynamic general equilibrium overlapping generation (DGE-OLG) models. Our model shares many key features with theirs, while differing in other key respects, so it is useful to describe these papers in some detail:

The influential model by Gervais (2002) emphasizes the downpayment requirement. He assumes a minimum house size and hence a minimum downpayment, but house size above that is continuous. Households must save to finance the downpayment, and also retirement. There is no fixed cost of buying/selling or adjusting mortgage size. In fact, mortgages are not long term contracts: the mortgage amount can be freely adjusted each period, provided the minimum equity (downpayment) requirement is satisfied. Home equity (in excess of the downpayment) can be used as collateral for home equity lines of credit. Hence the only state variable is total assets – how it is split between financial assets, home equity and a mortgage is irrelevant. Households are borrowing constrained as liquid assets must be positive (so net worth of homeowners is at least the downpayment).

Other features of Gervais' model are straightforward: The house price is constant in equilibrium, so there are no capital gains. Notably, he assumes a flat rate income tax. To capture heterogeneity across households, income is assumed to follow one of five deterministic life-cycle paths (corresponding to 5 quintiles of the income distribution).

Home ownership is a knife-edge decision in the model as (i) renting and owning are perfect substitutes in consumption, and (ii) rental property owners face a level tax system, and depreciation rates on rental and owner-occupied housing are equal. Hence, absent tax preferences, rent would equal the user cost of owner-occupied housing, so households are indifferent between owning and renting. But the subsidized user cost of owner-occupied housing caused by favorable tax treatment (non-taxation of imputed rents) causes anyone with enough savings to meet the downpayment requirement to prefer owning to renting.[4]

[4] As Henderson and Ioannides (1983) note, besides tax advantages, a more fundamental reason to prefer ownership is the high depreciation rate on rental property - arising because renters do not internalize costs of the wear and tear they generate - which drives up rents in equilibrium. Symmetrically, an owner may get greater utility from a unit of housing, as an owner is free to make utility enhancing modifications. A fundamental reason to prefer renting may arise if housing is a risky asset whose price fluctuates over time – ruled out in Gervais' model – and consumption demand exceeds investment demand.

Gervais (2002) finds that removing the mortgage interest deduction reduces the home ownership rate from 74% to 70%, while taxing imputed rents reduces it greatly to 57%.

Cho and Francis (2011) extend Gervais (2002) to incorporate transactions costs of changing house size, and a utility premium from ownership. They continue to assume house size is continuous above the minimum, and that agents can freely adjust mortgage size via home equity loans or prepayment of principle, so mortgages are not long term contracts. Other key simplifications are a flat rate income tax and AR(1) income process (no ex-ante heterogeneity). Removing the mortgage interest deduction has a negligible effect on the ownership rate in their model, but taxing imputed rent reduces it substantially from 64% to 41%. The fall in ownership is especially dramatic at young ages, as young households have less incentive to curtail consumption to save for a downpayment.

The model in Floetotto et al. (2016) is similar, but they further extend Gervais 2002 by allowing homeowners to rent out part of their property (thus becoming landlords) and by making house price endogenous by introducing a construction sector with less than perfectly elastic supply (the elasticity is 2.5). Other features that differ are a fixed interest rate, a mortgage interest premium, and lump sum transfers to balance the government budget (rather than adjusting the tax rate). In this model, eliminating the mortgage interest deduction causes ownership to drop from a 72% baseline to 58%, and taxing imputed rent causes it to drop dramatically to 40%.

Importantly, Chambers et al. (2009b) extend Gervais (2002) to 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. A fixed cost of buying/selling makes start-of-period house size a state variable. 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.

Chambers et al. (2009b) also use a more realistic specification of mortgages: They assume a 30-year fixed-rate mortgage with a 20% downpayment, which makes mortgage duration a state variable. Households can rent out part of their house and be landlords, and the rental price is determined in equilibrium. There are stochastic shocks to labor income at each age, and a persistent AR(1) component, but no permanent heterogeneity (which creates some problems in fitting the distribution of house sizes by age and income).[5] Importantly, they account for the progressive tax structure, which makes the mortgage interest deduction more valuable for higher income households. The house price is constant but there is an idiosyncratic capital gain shock when you sell, so housing has

[5] 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.

features of a risky investment in addition to being a consumption good.

Chambers et al. (2009b) simulate that eliminating the mortgage interest deduction would *increase* the home ownership rate from 64.6% to 65.3%, while average house size falls trivially. This is driven by the fact that tax rates fall in equilibrium (the interest rate falls very slightly). In a partial equilibrium experiment that ignores the drop in taxes, the rate of home ownership does fall by 3 percentage points. Similarly, they find that taxing imputed rent actually *increases* the rate of home ownership in equilibrium from 64.6% to 67.6%, while reducing average house size by 2.1%. Again, this is primarily because taxing imputed rents allows the tax rate to be lowered in equilibrium. Thus, the results in Chambers et al. (2009b) are radically different from those in Gervais (2002), Cho and Francis (2011) and Floetotto et al. (2016).

The model in Sommer and Sullivan (2018) is very similar to Chambers et al. (2009b). The key extension is that house price is endogenized (rather than assumed fixed). They estimate an elasticity of residential investment with respect to the price of housing of 0.90.[6] On the other hand, the model is simplified three key ways: Mortgages are modelled very simply as in Gervais (2002). The interest rate is also fixed. And this is not a full life-cycle model as there is no retirement and age is not a state variable, although there are overlapping generations with stochastic income profiles that tend to increase with age. There is no ex-ante heterogeneity.

Sommer and Sullivan (2018) find that eliminating the mortgage interest deduction would increase the home ownership rate from 65% to 70%. This occurs because the price of housing falls by a substantial 4.2%. Unlike in Chambers et al., imposing revenue neutrality in the experiment makes little difference, as the increase in revenue from eliminating the interest deduction is almost exactly offset by the drop in real estate taxes that occurs because house prices fall. They do not simulate taxation of imputed rent.

Thus, Chambers et al. (2009b) and Sommer and Sullivan (2018) both predict that eliminating the mortgage interest deduction would *increase* home ownership, but for fundamentally different reasons. In the former because it allows taxes to be reduced, in the latter because home prices fall. Both papers contradict Gervais (2002), who predicts that eliminating the mortgage interest deduction would cause ownership to fall modestly, and Cho and Francis (2011) and Floetotto et al. (2016), who predict it would fall substantially. Furthermore, Chambers et al. (2009b) and Sommer and Sullivan (2018) disagree sharply on magnitude of the increase in ownership – i.e., 0.7 percentage points vs. 5 percentage points.

[6] This is close to the 1.0 in Poterba (1984), but less than the 2.5 estimated by Floetotto et al. (2016). Sommer et al. (2013) assume housing stock is fixed in the same basic model, and find very large short-run effects of interest rates and downpayment requirements on house prices. As the magnitude of the long run elasticty is controversial, in our experiments we will consider both the unit elastic and infinitely elastic supply (i.e., fixed price) cases.

Berkovec and Fullerton (1992) take a very different approach. They calibrate a static general equilibrium model that emphasizes the dual role of housing as a consumption and investment good. In their model households of many representative types allocate their 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 treatment of housing and other assets is modelled in great detail. However, this model abstracts from the lumpiness of housing investment, and because it is static they abstract from transaction costs and long term mortgage contracts.[7]

Berkovec and Fullerton (1992) simulate a level treatment of housing where imputed rent is taxed would raise enough revenue to scale down all tax rates by 10%. This causes the ownership rate to increase by 0.8% while the owner-occupied housing stock falls 2.8%. There is a substantial drop in demand for housing among high income households. Eliminating the mortgage interest deduction 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).[8]

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 those papers, we estimate a life-cycle model in partial equilibrium, treating house prices and the interest rate as exogenous. The advantage of our approach is that the computational savings from treating prices as exogenous is that we can make our model richer along several other dimensions, as we already discussed in the introduction. We describe our model in the next section.

[7] They assume a fixed cost of holding a positive position in any asset class. Thus, 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. But, not surprisingly, the most important factor determining whether a household owns housing is simply demographics.

[8] 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 consequence of which was to reduce the importance of the mortgage interest deduction by lowering top rates. They predict that TRA86 would have allowed a 9% reduction in tax rates in a revenue neutral simulation. They simulate a slight increase in the ownership rate from 62.3% to 62.7%, as demand for housing fell for high income households but increased for low income households.

3 The Life-Cycle Model

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 only 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.[9]

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 $j_t^r \in \{0, ..., 5\}$.

3.1 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.

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.

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

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:

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

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:

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

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. Then, following Campbell and Cocco (2015), we assume the bequest utility function:

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

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

3.2 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_t^o. The household's beginning of period t mortgage payment equals $M_{t-1}^o(1 + r_m) - M_t^o$, as we explain in more detail Section 3.5. So we can write the annual housing cost for an owner-occupied house $Hcost_t^o$ as:

$$Hcost_t^o = H_t(j_t^o)(\phi^u + \tau^o + \delta^o) + M_{t-1}^o(1 + r_m) - M_t^o \quad (4)$$

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. To account for various costs confronting owners, 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:

$$Hcost_t^k = H_t(j_t^k)(\tau^k + \delta^k - \alpha \cdot s^k) + M_{t-1}^k(1 + r_m^k) - M_t^k \tag{5}$$

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.

3.3 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:

$$H_t(j) = P_t^H h^j \tag{6}$$

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. 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:

$$P_{t+1}^H = P_t^H(1 + \varepsilon_{h,t+1}) \;\; \text{where} \;\; \varepsilon_{h,t+1} \sim MN(-5\%, +1\%, +7\%;\; 1/3, 1/3, 1/3) \tag{7}$$

Equation (7) 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 Financial Assets

Our model is simplified by assuming the agent can invest its (non-negative) stock of savings S_t in only 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 $R^f = 1 + r^f$.

3.5 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:[10]

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

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 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.

[10]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.

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.

3.6 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. 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.[11] 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:

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

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

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.

[11] 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.

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

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

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

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

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.[12] To finesse this

[12] 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.

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).[13] 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.

3.8 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.

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 5.2.2.

[13] In other words, if the value of your house goes up from last year, you pay the tax on that increase immediately. That means there is no tax when you sell. You have already paid taxes on the capital gains in the past on an accrual basis.

3.9 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 3.1.

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:

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

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:

$$C_t > 0, S_t \geqslant 0 \tag{30}$$

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,[14] 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).

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] 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.

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 $j_t^o = j_{t-1}^o$, and make the mortgage payment $MP_t^o = M_{t-1}^o(1 + r_m) - M_t^o$. And at the start of period $t + 1$ the first two state variables will be $\{H_{t+1}(j_t^o), M_t^o\}$. Alternatively, if the household wants to change house size, they choose $j_t^o \neq j_{t-1}^o$. Then, they must pay off the mortgage balance plus interest, $M_{t-1}^o(1+r_m)$, and they receive as the sale price the time t value of the house $H_t(j_{t-1}^o)$. 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 $\{H_{t+1}(j_t^o), M_t^o\}$, but the numerical values of these two state variables are of course different from the previous case.

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 $\{H_t(j_{t-1}^k), M_{t-1}^k\}$. 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

Conditional on it's state, the household makes optimal decisions about housing, investment property and consumption. The choice set may be written $d_t = \{j_t^o, j_t^k, j_t^r, C_t\}$ 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 $j_t^o \cdot j_t^r = 0$. We also assume that renters cannot own investment property, so $j_t^k \cdot j_t^r = 0$. 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 $d_t^H = \{j_t^o, j_t^k, j_t^r\}$.

4.3 The Dynamic Optimization Problem

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

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

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 for the exogenous state variables (house price, income, kids) in (6), (22), (25), the price expectation process in (7), 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 2009). 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 $IC_t(X_t^h)$:

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

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.[16]

[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.

[16] In nested logit terminology this is called the "inclusive value" from taking the expected maximum over options in the second-stage 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:

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

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

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.[17]

To set up the grid, we use 6 grid points for house values (zero and the median price of

[17] 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.

1 through 5 bedroom houses),[18] 5 grid points for mortgage values (0, 20, 40, 60 and 80% of house value), and 11 grid points for savings.[19] 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 $IC_{T-1}(X_{T-1}^h)$.[20] 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.

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

[19]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.

[20]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.[21]

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.[22] 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 investment *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

[21] 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.

[22] 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.

is $\tau^k = 2\%$.

We set the real risk-free interest rate to 3%, and the real mortgage interest rate to 5%. Similarly, Campbell and Cocco (2015) assume the mortgage rate is 1.8 percentage points 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%. We list the nominal mortgage interest rates we use to calculate the mortgage interest deduction in Table B7. The data for 1971 to 2022 are average rates compiled by Freddie Mac 2022. They did not collect data in 1968-71, so we set the rate for those years to 7%.

According to U.S. Census Bureau 2001, the median price-to-rent ratio for single unit rental properties in 2000 was 10, so we calibrate the rent/value ratio α to .10.[23] We set the landlord's share of rent, net of commissions etc., s^k to .91. Together these values imply landlords break even on average, as $r_m^k + \delta^k + \tau^k$ - mean annual appreciation = .0575 + .0244 + .02 - .0108 = .091, so the net rent equals the cost of holding a property.

The annual mortality rate $(1-\rho_t)$ is calibrated to the 1998 life table for the total U.S. population (CDC 2009). 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/.[24]

5.2 Parameters of Exogenous Processes: Prices, Income, Kids

5.2.1 House Prices

We calibrate the real house price index P_t^H in (6) using the Case-Schiller (CS) index from 1968 to 2019 as in Shiller (2019), presented in Appendix Table B4. We convert all nominal quantities to real 1999 dollars using the CPI in Shiller (2019), see Table B4. Thus we normalize $P_t^H = 1$ when t corresponds to 1999.

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.[25] However, there were substantial year-to-year fluctuations around that trend, as we see in Figure 1 and Table B4. Looking at annual real house price changes from 1968-2019, the mean annual change is 1.08%, 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 (6), using the median values of 1 to 5-bedroom owner-occupied homes in the

[23] 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.

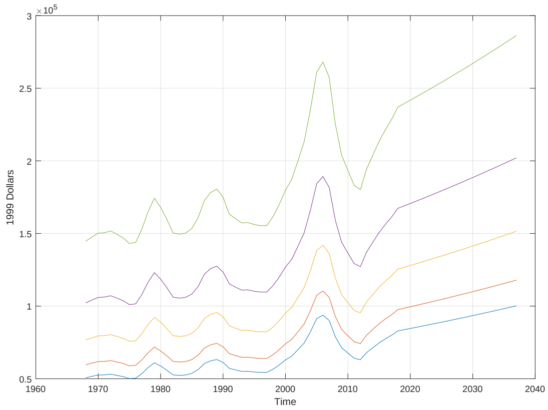
[24] From 2019 onward we assume the tax structure is constant.

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

PSID in 1999. We obtain \$59.5k, \$70k, \$90k, \$120k and \$170k, respectively.[26,27]

Under our assumption that *relative* prices of 1 through 5 bedroom houses stay fixed over time, we can use (6), 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 – see Erdem et al. (2003).

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



While, the actual house price in the model follows the Case-Schiller index, the agents in the model do not know in advance how much house prices will change each year. We assume that agents 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.

5.2.2 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

[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.

[27] 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.

per year; see Table B5. 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.

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[28] and then subtract off asset and rental income.[29]

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. The estimates are reported in 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, indicating there is substantial heterogeneity in household earnings capacity within education groups.

Table 2: Household Income Process

Parameter	Description	$<$ HS	High School	College
	% of Cohort	32.200	50.700	17.100
l_0	Constant	7.587(0.423)	8.341(0.289)	7.218(0.529)
l_1	Age	.138(0.029)	.104(0.020)	.188(0.035)
l_2	$Age^2/100$	-.224(0.063)	-.133(0.042)	-.283(0.074)
l_3	$Age^3/1000$	.011(0.004)	.003(0.003)	.012(0.005)
l_4	Age $>$ 65	.024(0.072)	-.020(0.048)	.030(0.070)
l_5	Kids at Home	.103(0.023)	.052(0.018)	-.001(0.033)
	σ_{RE}	.572	.531	.551
	$\sigma_{Transitory}$	.437	.419	.429
	Data mean	$32304	$43930	$68043
	Sim. Data mean	$31073	$44055	$68896
	Households	393	397	113
	Observations	3270	5154	1735

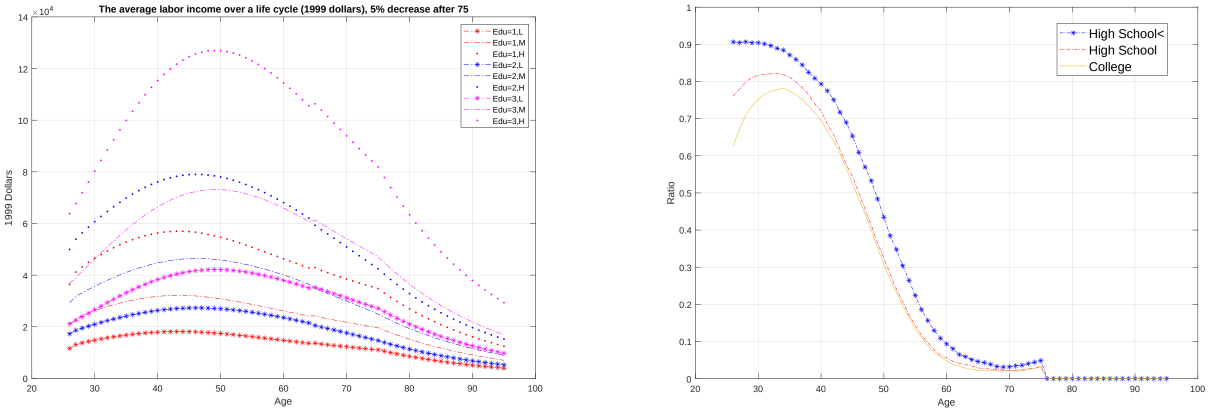
Based on these results, we decided to set the low, medium and high levels of the household specific intercept in equation (24) to ($-\sigma_{RE}$,0,σ_{RE}), where σ_{RE} is the standard deviation of the random effects reported in Table 2. Within each education group, we assume 1/3 of the households fall into each of the low, medium and high intercept types. This set up implies that $\sigma_\mu = \sqrt{2/3} \cdot \sigma_{RE}$.

[28]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.

[29]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 358 of 10460 total observations are dropped.

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.[30] The simulated life-cycle income paths for each of our 9 types are shown in Figure 2, left panel.

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 Table 3. After retirement (i.e., 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.

Table 3: Process for Kids

Parameter	Description	Value(s.d)
a_0	Constant	-1.304(0.217)
a_1	$(Age-25)$	0.007(0.036)
a_2	$(Age-25)^2/100$	-0.574(0.176)
a_3	$(Age-25)^3/1000$	0.089(0.024)
a_4	Kids(t-1)	5.156(.098)
a_5	Education=HS	-0.249(0.106)
a_6	Education=COL	-0.298(0.135)
	Households	713
	Observations	9308

5.3 Structurally Estimated Parameters

The model contains 21 utility function parameters that we estimate structurally via the method of simulated moments. 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 4, and discuss the statistics that we match in Section 5.3.2.

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

5.3.1 Structural Estimates

As we see in Table 4, 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 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 less than one, implying the utility function is slightly more concave than the log in both housing and non-housing consumption.

Table 4: Structurally Estimated Utility Parameters

Parameter	Description	Estimate	(Std Err)
γ	CRRA, Non-housing Consumption	1.1136	(0.0572)
δ	CRRA, Housing Consumption	1.1420	(0.1614)
$R(1)$	Housing services, 1-bedroom house	1.3950	(0.0739)
$R(2)$	Housing services, 2-bedroom house	2.1750	(0.1072)
$R(3)$	Housing services, 3-bedroom house	2.4000	(0.1458)
$R(4)$	Housing services, 4-bedroom house	3.0600	(0.2112)
$R(5)$	Housing services, 5-bedroom house	3.4200	(0.2609)
$\mu(1)$	Utility loss from renting, 1-bedroom	.8023	(0.0524)
$\mu(2)$	Utility loss from renting, 2-bedroom	.7470	(0.0524)
$\mu(3)$	Utility loss from renting, 3-bedroom	.6680	(0.0524)
$\mu(4)$	Utility loss from renting, 4-bedroom	.6056	(0.0524)
ψ_1	Taste for Housing, family with kids	.3786	(.0364)
ψ_0	Taste for Housing, family without kids	.3590	(0.1092)
ψ_{0a}	Multiplier of ψ_0, Age < 45	.3996	(0.0512)
Δ_s^o	Utility loss, Owner to renter	.0276	(0.0063)
Δ_b^k	Utility loss, Become a landlord	.0274	(0.0070)
Δ_s^k	Utility loss, Landlord to non-landlord	.0271	(0.0071)
η	Strength of Bequest Motive	14.1271	(1.7876)
λ^c	Scale of Taste Shocks, Consumption choice	.0350	(0.0088)
λ^h	Scale of Taste Shocks, housing services choice	.0672	(0.0054)
θ_h	Age effect on scale, housing choice	.4449	(0.2053)

As expected, the service flow from housing, captured by $R(1)$ to $R(5)$, is increasing in the number of bedrooms; except that a 5-bedroom generates, on average, little more utility than a 4-bedroom. It is worth noting that, in our model, a household that chooses a j-bedroom house tends to have a high realization of the taste shock v_{d^H} corresponding to that choice – see (36). So households that buy a house of size j tend to get more utility from that house size than $R(j)$, the average utility, would imply.

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. The estimates of ψ imply that *young* households (age<45) without kids get relatively very little utility from housing.

The estimates also imply there is a utility loss from going from owner to renter, and there are substantial utility losses from changing landlord status. The later may capture the time costs of buying/selling rental property, finding tenants, learning to deal with the accounting/tax issues, etc. Finally, as $\theta_h<1$ the taste shocks for housing options grow less important with age.

5.3.2 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 obvious reason is the PSID was semi-annual after 1997. Furthermore, not every variable was collected in every survey. A key advantage of MSM is that we can construct moments based on simulated vs. actual data using only years when the actual data are available. Table B5 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.[31] 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.[32]

We calculate household financial (or, more precisely, non-housing) assets in the PSID

[31] We eliminate the rare cases where a household that rents also owns an investment property.

[32] We drop cases where the mortgage or investment property equity exceeds $500000 in 1999 dollars.

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.[33]

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.

In the PSID, both housing and non-housing expenditure were measured more comprehensively over time. Before 2003, housing expenditure included mortgage interest, rent, property tax, insurance and utilities. After 2003, other variables, such as home repairs, are included. Before 2003, nonhousing expenditure included food, transport, education, childcare and health care. After 2003, clothing, trips and recreation, cable TV, internet, telephone, home furnishings and computers were added. To adjust for these changes, we compare expenditure in the PSID vs. the more comprehensive Consumer Expenditure Survey (CES). 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. The computed scales over time are listed in Table B6.

6 Model Fit

In this section we describe the fit of the model to a subset of the statistics that we listed in Section 5.3.2. We only report those we consider most important:

First, Table 5 shows the fit to the home ownership rate. The model fits the overall ownership rate of 64.9% almost exactly. Table 5 also shows how we fit the ownership rate by age. The overall fit is quite good. The model captures the increases in the ownership rate from ages 26 to 54 very well. In the data the ownership rate jumps from 45.7% at ages 26-34 to 68.4% at ages 45-54. The comparable rates in the model are 43.5% and 71.9%. 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%.

[33] Observations in the top 3.5% of net worth (above \$1.75 million in 1999 dollars) are dropped.

Finally, the bottom of Table 5 reports home ownership by education. The model understates the ownership rate of the high school dropouts (53.8% in the data vs. 45.6% in the model) while overstating that of college graduates (77.5% in the data vs. 84% in the model). So we slightly exaggerate the gradient of ownership with education.

Table 5: Home Ownership Rates, Data vs. Model

Variable	Data	Model
Ownership Rate	.649	.649
Ownership by Age		
Age 26-34	.457	.435
Age 35-44	.665	.678
Age 45-54	.684	.719
Age 55-64	.770	.721
Age 65-77	.785	.712
Ownership by Education		
Less than HS	.538	.456
High School	.677	.707
College	.775	.840

Table 6 shows annual transition rates between owner and renter status. 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 6: Transition Rates, Data vs. Model

Annual Rate	Data	Model
Owner to Owner	.940	.934
Renter to Owner	.111	.155

As we see in Table 7, the model fits the distribution of home sizes very accurately. The average home size for all households, including both owners and renters, is 2.818 bedrooms in the data vs. 2.80 in the model. 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 7: 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	.27	.531	.527
3 Bedroom	.220	.219	.263	.262	.140	.144
4 Bedroom	.253	.251	.339	.342	.093	.094
5 Bedroom	.063	.062	.098	.097	.000	.000
Mean Size	2.818	2.801	3.211	3.21	2.092	2.097

Table 8 shows how we fit the distribution of home sizes by age. The average home size increases from 2.71 bedrooms at ages 26-45 to 2.96 bedrooms at ages 46-65, and the model captures this increase accurately (giving 2.68 and 2.95, respectively). Surprisingly, in the data the average house size continues to increase to 3.02 bedrooms at ages 66-77, while in the model it declines to 2.86. It is difficult for an economic model to rationalize why households don't downsize at older ages.

Table 8: Home Sizes by Age, Data vs. Model

Model			
	26-45	46-65	66-77
1 Bedroom	.118	.080	.123
2 Bedroom	.398	.336	.297
3 Bedroom	.214	.217	.245
4 Bedroom	.221	.289	.266
5 Bedroom	.048	.078	.070
Mean Size	2.684	2.949	2.863
Data			
	26-45	46-65	66-77
1 Bedroom	.100	.096	.120
2 Bedroom	.397	.332	.265
3 Bedroom	.233	.202	.207
4 Bedroom	.238	.257	.290
5 Bedroom	.032	.112	.118
Mean Size	2.705	2.957	3.022

Note: Distribution of home sizes for all households (both renters and owners).

Table 9 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 9: Home Sizes by Education, Data vs. Model

All	Less than HS		High School		College	
	Data	Model	Data	Model	Data	Model
1 Bedroom	.123	.193	.088	.072	.094	.033
2 Bedroom	.447	.430	.373	.373	.208	.214
3 Bedroom	.225	.206	.241	.221	.160	.237
4 Bedroom	.169	.160	.240	.286	.393	.317
5 Bedroom	.036	.011	.058	.047	.146	.199
Mean Size	2.546	2.365	2.808	2.864	3.288	3.437

Note: Distribution of home sizes for all households.

Table 10 shows the fit to the fraction of households that own investment property. The model fits the overall rate of 21% almost exactly. From ages 45 to 77 the fraction of households that hold investment property is fairly flat in both the model and data. We do not observe investment property ownership in the PSID at earlier ages, but the model predicts it rises substantially from ages 26 to 44. The model also captures how ownership of investment property varies by education, except it exaggerates the fraction of college educated households that are landlords (43.2% in the model vs. 33.2% in the data).

Table 10: Investment Property, Data vs. Model

Variable	Data	Model
Landlord Rate	.210	.215
Landlord Rate by Age		
Age 26-34	-	.103
Age 35-44	-	.237
Age 45-54	.184	.223
Age 55-64	.225	.238
Age 65-77	.226	.194
Landlord Rate by Education		
Less than HS	.106	.091
High School	.198	.220
College	.332	.432

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

Table 11 shows the fit to financial assets and net worth, both overall and by age. We can only compare those ages for which the PSID reports these variables, as shown in the table. Overall the fit is quite good, except the model slightly understates the mean of financial assets at age 42 ($76k in the model vs. $104k in the data).

Table 11: Financial Assets and Net Worth, Data vs. Model

Variables	Data	Model
Financial Assets by Age ($)		
Overall	157,454	164,006
Age 42	104,212	76,125
Age 47	128,205	122,238
Age 52, 57 to 64	157,472	172,455
Age 65-77	184,346	194,791
Net Worth by Age ($)		
Overall	217122	224,879
Age 42	118,516	100,582
Age 47	161,924	160,318
Age 52, 57 to 64	235,100	241,590
Age 65-77	264,750	265,941

Finally, Table 12 shows how the model fits financial variables, separately for one-home owners, landlords (who own both a home and an investment property), and renters (who we assume hold no investment property). We examine the home value, home loan value, financial assets and net worth. The model fits these variables very well for one-home owners and landlords. A key shortcoming of the model is that it overstates the mean financial assets of renters, which is $91k in the model vs. $36k in the data. Recall from

Table 11 that this mean is taken over ages 42, 47, 52, and 57-77, which is when assets are recorded in the PSID. So the model is exaggerating assets of older renters. Recall that the model also exaggerates the number of older renters, Table 5. These two problems are obviously linked.

Table 12: Assets by Ownership Status, Data vs. Model

Variables	Data	Model
One-home owners ($)		
Home value	98,982	98,341
Home loan	36,562	56,133
Financial assets	171,063	166,082
Net worth	217,384	234,985
Landlords ($)		
Home value	136,450	142,137
Home loan	38,377	55,659
Rental equity	45,000	42,642
Financial assets	262,601	266,889
Net worth	408,827	396,009
Renters ($)		
Financial assets	36,496	90,787

Note: Home value and loan amounts are observed in all PSID waves from 1968. Financial assets, investment house equity, and net worth were first observed in 1984. See Table B5.

7 Results

The following sections report our results. In Sections 7.1 through 7.4 we describe how demand for housing differs across types of households, and how it responds to changes in income, prices and income tax rates. Then in Sections 7.5 to 7.7 we present our key results where we examine how changes in the tax treatment of housing affect demand for housing and consumer welfare. We consider taxing imputed rent, eliminating the mortgage interest deduction, and implementing a refundable mortgage interest tax credit.

7.1 Heterogeneity in Demand for Housing

Table 13 shows how demand for housing differs by education in the model. For each education group we also list average income, as this is the key factor that drives differences in their demand for housing. The education types also differ modestly in probability of having children at home, as we saw in Figure 2, but these differences are not large enough to create large differences in demand for housing across types.

Note that the high school group has average income 41.2% higher than the <HS group. The average home size of the high school group, including both owners and renters, is 21.1% greater than that of the <HS group (2.864 vs. 2.365 bedrooms). The implied income elasticity of demand for housing is 19.3/41.2 = .51. (Note: Throughout the paper

we use the average home size over both owners and renters as a measure of overall demand for housing services.) Similarly, the average income of the College type is higher than the HS type by 55.3%, and their average home size is greater by 20%, implying an income elasticity of 20.0/55.3 = .36. As these elasticities are both less than 1.0, housing behaves like a necessity. Notice that the income elasticity falls as income increases.

Table 13: Demand for Housing by Education

	Ownership Rate	Income	Home size All	Home size Homeowners
Less than HS	.456	32044	2.365	2.968
High School	.707	45251	2.864	3.134
College	.840	70271	3.437	3.640

The behavior of the ownership rate is very different. The HS type has income 41.2% higher than the <HS type, and their ownership rate is 55.0% greater, implying an income elasticity of demand for ownership of 55.0/41.2 = 1.33. In contrast, the college type has income 55.3% higher than the HS type, and their ownership rate is greater by only 18.8%, implying an income elasticity of demand for ownership of only 18.8/55.3 = .34. Thus, ownership is far more sensitive to income at the low end. This is largely due to to the down-payment requirement and the PTI constraint.

In Table 14 we show 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.[34] 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 .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 14: Demand for Housing by Household Type

Type	Education	Skill	Income	Ownership Rate	Home size All	Home size 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

[34] There is a great deal of income heterogeneity within education levels – e.g., the high skill HS type earns more than the medium and low skill college types.

Turning to the ownership rate, we see it 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. For instance, if we compare type 3 (<HS, Med) with type 2 (HS, Low) the ownership rate increases by 19.5% while average income increases by 18.7% implying an elasticity of 1.04. But if we compare type 9 (Col, High) with type 8 (HS, High) the ownership rate increases by 3.1% while average income increases by 55.4% implying an elasticity of only .06.

7.2 Income Elasticity of Demand for Housing

Table 15 column 2 reports an experiment where we reduce income by 10% for all households. The reduces average home size for all households (both owners and renters) from 2.801 bedrooms to 2.643 bedrooms, a 5.6% drop. Thus, the overall income elasticity of demand for housing is .56. In Table 16 we break down these results by education and find the income elasticity of demand is .81 for <HS, .48 for HS and .43 for college.

Table 15: Income, Price and Tax Rate, Experiments

	Baseline	Income -10%	Income +10%	Price -10%	Price +10%	Tax R. -10%
	(1)	(2)	(3)	(4)	(5)	(6)
Ownership Rate	0.649	0.584	0.680	0.681	0.595	0.649
Average Home Sizes						
All People	2.801	2.643	2.943	2.948	2.680	2.811
Owners	3.210	3.147	3.331	3.339	3.156	3.218
Renters	2.097	1.980	2.170	2.165	2.028	2.108
Ownership Rate by Age						
Age 26-35	0.435	0.368	0.481	0.480	0.375	0.438
Age 36-45	0.678	0.606	0.704	0.702	0.623	0.676
Age 46-55	0.719	0.664	0.738	0.739	0.675	0.718
Age 56-65	0.721	0.655	0.758	0.765	0.660	0.722
Age 66-77	0.712	0.650	0.756	0.765	0.654	0.714
Landlord Rate	0.215	0.169	0.260	0.267	0.170	0.214

Notes: (1) Baseline model, (2) Reduce income 10%, (3) Increase income 10%, (4) Reduce house prices 10%, (5) Increase house prices 10%, (6) Reduce income tax rates 10%.

When we reduce income 10% the ownership rate drops from 64.9% to 58.4%, a 10% decline. But effects differ greatly by household type. In Table 17, we see that the second poorest type (HS, Low) experiences a substantial drop from 40.5% to 23.0%, as many of them can no longer afford even the very small houses they buy in the baseline. The ownership rate of the third poorest type (HS, Med) drops substantially, from 48.4% to

40.6%. At the other end of the spectrum, the wealthiest type (Col, High) only reduce their ownership slightly from 97.4% to 96.7%, and they only reduce their average owner-occupied house size from 4.199 bedrooms to 4.139 bedrooms, or 1.4%.

If we instead *increase* income by 10% the ownership rate only increases from 64.9% to 68.0%, a 4.8% increase (compared to the 10% decline when we *reduced* income). This asymmetry is largely driven by the behavior of type 2, the (HS, Low) type. In the baseline many of them can just barely afford a small house, so reducing their income causes their ownership rate to drop substantially. In contrast, if we increase their income by 10% their ownership rate only increases slightly from 40.5% to 41.9%. But some type 2s decide to delay home purchase and save up the down-payment for a larger house, so their average owner-occupied house size increases from 1.916 to 2.166 bedrooms, a 13% increase.

Increasing income 10% causes average home size (for both owners and renters) to increase from 2.801 to 2.943, or 5.1%. This is close to the 5.6% decline if we reduce income. This near symmetry contrasts with the asymmetry we saw for the ownership rate. The overall demand for housing (owned+rented) behaves differently from the ownership rate, due to the discreteness of housing interacting with the downpayment/PTI constraints.

The demand for investment property is very sensitive to income. A 10% drop in income causes the fraction of households who hold investment property to drop from 21.5% to 16.9%, while a 10% increase in income causes it to increase to 26.0%. The data pattern that drives this result is obvious: Recall from Table 10 that in the PSID data the college households are 213% more likely to hold investment property than those where the head has less than high school education. In contrast, as we saw in 5 their home ownership rate is only 44% greater. So the gradient of investment property ownership with household earning capacity is about 5 times steeper than the ownership gradient.

7.3 Price Elasticity of Demand for Housing

Column 5 of Table 15 reports an experiment where we increase the real price of housing by 10% in all years. This causes *both* house prices and rental cost to increase by 10%. The average home size (including both owners and renters) drops from 2.801 to 2.680, a 4.3% decline. So the uncompensated price elasticity of demand for housing is 0.43. It is important to note that this elasticity is not comparable to any reported in the literature, as we are simulating the long run effect on demand of both house and rental prices being 10% higher over the entire life-cycle.

Table 16 beaks down these results by education level. For the <HS, HS and college households the average home size drops by 5.1%, 4.2% and 3.5%, respectively. Thus, the price elasticity of demand for housing is declining with income.

The ownership rate is much more sensitive to price than overall demand for housing. As we see in column (5), a 10% price increase reduces the ownership rate from 64.9% to

Table 16: Income, Price and Tax Rate, by Education

	Baseline (1)	Income -10% (2)	Income +10% (3)	Price -10% (4)	Price +10% (5)	Tax R. -10% (6)
<High School						
Ownership Rate	0.456	0.415	0.499	0.504	0.418	0.458
Landlord Rate	0.091	0.044	0.138	0.143	0.044	0.090
Home size-All	2.365	2.173	2.502	2.510	2.244	2.374
Home size-Owners	2.968	2.868	3.059	3.080	2.901	2.970
High School						
Ownership Rate	0.707	0.619	0.732	0.730	0.636	0.705
Landlord Rate	0.220	0.170	0.270	0.276	0.172	0.221
Home size-All	2.864	2.725	3.022	3.027	2.743	2.877
Home size-Owners	3.134	3.096	3.294	3.302	3.091	3.150
College						
Ownership Rate	0.840	0.801	0.866	0.867	0.809	0.842
Landlord Rate	0.432	0.402	0.461	0.475	0.402	0.428
Home size-All	3.437	3.289	3.540	3.539	3.317	3.440
Home size-Owners	3.640	3.532	3.713	3.711	3.551	3.638

Notes. See notes for the Table 15.

59.5%, or 8.3%. So the price elasticity of demand for ownership is .83. As we see in Table 17, the ownership rate for type 2 (HS, Low) drops substantially from 40.5% to 26.2%. The drops are smaller but still substantial for types 3, 4 and 5 (about 6 percentage points each), while the wealthier types 6 to 9 are little affected.

If we instead *reduce* house prices by 10% the ownership rate only increases from 64.9% to 68.1%, a 4.9% increase, implying a price elasticity of demand for ownership of only .49 (compared to .83 when we raise price). The asymmetry between price increases and decreases is again driven by the behavior of the type 2s (HS, Low). They are already buying very small houses in the baseline, so when house prices increase by 10% many of them are priced out of the market. But when prices fall by 10% their ownership rate only increases slightly from 40.5% to 44.8%, as they respond by waiting longer to save up for a larger house. In fact, their average owner-occupied house size increases from 1.916 to 2.183 bedrooms, a substantial 14% increase.

Over all households, the average home size increases from 2.801 to 2.948 bedrooms, a 5.2% increase, so the price elasticity of demand is slightly larger when we consider a price decrease (.52) than when we consider a price increase (.43). If we utilize information from both the price increase and decrease we obtain an arc elasticity estimate of .476.

The demand for investment property is very sensitive to price. A 10% price increase causes the fraction of households who hold investment property to drop from 21.5% to 17%, a 21% decline. And a 10% price decreases causes the share of households who hold investment property to increase to 26.7%, a 24% increase.

Table 17: Income, Price and Tax Rate, by Type

	Baseline (1)	Income -10% (2)	Income +10% (3)	Price -10% (4)	Price +10% (5)	Tax Rate -10% (6)
1. <HS, Low						
Ownership Rate	0.001	0	0.006	0.007	0	0.001
Home Size - All	1.547	1.226	1.709	1.691	1.376	1.560
Home Size - Owners	1	-	1.079	1.179	-	1
2. HS, Low						
Ownership Rate	0.405	0.230	0.419	0.412	0.262	0.398
Home Size - All	2.033	1.929	2.193	2.203	1.942	2.049
Home Size - Owners	1.916	1.767	2.166	2.183	1.756	1.931
3. <HS, Med						
Ownership Rate	0.484	0.406	0.574	0.586	0.412	0.485
Home Size - All	2.315	2.166	2.461	2.482	2.195	2.326
Home Size - Owners	2.337	2.119	2.531	2.565	2.149	2.346
4. Col, Low						
Ownership Rate	0.639	0.554	0.694	0.696	0.573	0.644
Home Size - All	2.668	2.469	2.780	2.786	2.507	2.678
Home Size - Owners	2.829	2.608	2.930	2.937	2.646	2.839
5. HS, Med						
Ownership Rate	0.768	0.701	0.815	0.817	0.714	0.768
Home Size - All	2.876	2.732	3.047	3.046	2.755	2.891
Home Size - Owners	2.985	2.841	3.161	3.158	2.864	2.998
6. <HS, High						
Ownership Rate	0.880	0.837	0.913	0.914	0.841	0.884
Home Size - All	3.232	3.122	3.333	3.354	3.157	3.234
Home Size - Owners	3.319	3.230	3.406	3.427	3.267	3.318
7. Col, Med						
Ownership Rate	0.897	0.873	0.920	0.920	0.875	0.898
Home Size - All	3.443	3.263	3.602	3.595	3.300	3.449
Home Size - Owners	3.554	3.379	3.702	3.694	3.418	3.557
8. HS, High						
Ownership Rate	0.945	0.924	0.958	0.958	0.928	0.946
Home Size - All	3.678	3.511	3.822	3.828	3.529	3.688
Home Size - Owners	3.745	3.589	3.880	3.885	3.605	3.753
9. Col, High						
Ownership Rate	0.974	0.967	0.979	0.980	0.968	0.975
Home Size - All	4.155	4.084	4.196	4.194	4.094	4.147
Home Size - Owners	4.199	4.139	4.230	4.228	4.149	4.189

Notes. See notes for Table 15.

7.4 Effect of the Income Tax on Demand for Housing

The last column of Table 15 reports an experiment where we reduce all tax rates by 10% in all years. For example, if the top marginal rate was 40% in a particular year we reduce it to 36%, and reduce all other marginal rates by 10% as well. Interestingly, this has almost no effect on the ownership rate or average house size. The reason is that a tax reduction has two offsetting effects: There is a positive income effect on demand for owner-occupied housing, as we saw in columns 2 and 3. But at the same time reducing marginal rates reduces the value of the tax advantages of owner-occupied housing - the mortgage interest deduction, the non-taxation of imputed rent, and the capital gains exemption. In the following sections we examine the impact of these tax advantages on demand for housing.

7.5 Policy Experiment 1: Tax Net Imputed Rental Income

7.5.1 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 wants to treat owner-occupied housing exactly 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 18 column 2, taxing net imputed rent causes the ownership rate to drop substantially from 64.9% to 59.0%, an 9.1% decline. The drop is greater among lower income households. As we see in Table 19, for households where the head has less than HS education, the ownership rate drops form 45.6% to 40.2%, an 11.8% decline. For households where the head has HS or college education the drops are 10.0% and 4.3%.

Table 18: 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 3 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.

Interestingly, the average owner-occupied home size actually increases very 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. As we see in Table 20, the ownership rate of the wealthiest households is little affected: The type 9's rate drops only from 97.4% to 97.1%, and their average house size only drops from 4.155 to 4.132 bedrooms. In contrast, for the 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 the effects are even greater: The ownership rate of the 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%. These are substantial 24% and 31% declines, respectively.

Table 19: Tax Net Imputed Rent, Results by Education

	Baseline (1)	Partial Equilibrium (2)	Revenue Neutral (3)	Equilibrium Price (4)
<High School				
Ownership Rate	0.456	0.402	0.407	0.411
Home size-All	2.365	2.323	2.333	2.346
Home size-Owners	2.968	2.935	2.94	2.955
High School				
Ownership Rate	0.707	0.637	0.644	0.647
Home size-All	2.864	2.824	2.837	2.848
Home size-Owners	3.134	3.158	3.163	3.172
College				
Ownership Rate	0.840	0.804	0.813	0.815
Home size-All	3.437	3.393	3.398	3.403
Home size-Owners	3.640	3.634	3.625	3.629

Note: See notes for Table 18.

Taxing imputed rent raises substantial revenue, so in a revenue neutral simulation we cut income tax rates by 9.15%. The results of this experiment are shown in Table 18 column 3. The tax cut only leads to only a slight rebound in the ownership rate, from 59.0% to 59.6%. This is consistent with our finding in Table 15 column 6 that tax cuts of a similar magnitude (10%) have very little effect on demand for owner-occupied housing.

As we also see in Table 18 column 3, in a revenue neutral simulation taxing imputed rent has little impact on the average home size over all households, which only drops from 2.801 to 2.770 bedrooms, a 1.1% drop. Hence a tax on imputed rent has only a small impact on the overall demand for housing in the economy. It mostly shifts demand away from owner-occupied housing towards rental housing.

The drop in demand for housing will cause a drop in the price of housing in equilibrium (unless housing supply is infinitely elastic in the long run). To calculate the new equilibrium price we close the model by assuming an iso-elastic supply of housing, as in Poterba (1984) and Sommer and Sullivan (2018). They obtain elasticities of 1.0 and 0.9, respectively. Here consider a value of 1.0. Given this value, we calculate that in the new equilibrium the price of housing drops by 0.714%.[35]

Table 18 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.

Table 20: Tax Net Imputed Rent, Results by Type

	Baseline (1)	Partial Equilibrium (2)	Revenue Neutral (3)	Equilibrium Price (4)
1. <HS, Low				
Ownership Rate	0.001	0.001	0.001	0.001
Home Size - All	1.547	1.547	1.559	1.569
Home Size - Owners	1	1	1	1
2. HS, Low				
Ownership Rate	0.405	0.280	0.285	0.292
Home Size - All	2.033	2.049	2.058	2.065
Home Size - Owners	1.916	1.883	1.883	1.900
3. <HS, Med				
Ownership Rate	0.484	0.366	0.374	0.382
Home Size - All	2.315	2.288	2.298	2.308
Home Size - Owners	2.337	2.276	2.283	2.300
4. Col, Low				
Ownership Rate	0.639	0.552	0.572	0.576
Home Size - All	2.668	2.603	2.616	2.623
Home Size - Owners	2.829	2.773	2.774	2.782
5. HS, Med				
Ownership Rate	0.768	0.695	0.706	0.708
Home Size - All	2.876	2.796	2.817	2.826
Home Size - Owners	2.985	2.911	2.927	2.937
6. <HS, High				
Ownership Rate	0.880	0.839	0.846	0.850
Home Size - All	3.232	3.129	3.140	3.160
Home Size - Owners	3.319	3.223	3.231	3.252
7. Col, Med				
Ownership Rate	0.897	0.881	0.885	0.887
Home Size - All	3.443	3.396	3.400	3.407
Home Size - Owners	3.554	3.515	3.514	3.521
8. HS, High				
Ownership Rate	0.945	0.933	0.936	0.937
Home Size - All	3.678	3.623	3.632	3.649
Home Size - Owners	3.745	3.699	3.703	3.721
9. Col, High				
Ownership Rate	0.974	0.971	0.972	0.973
Home Size - All	4.155	4.132	4.130	4.134
Home Size - Owners	4.199	4.178	4.174	4.177

Note: See notes for Table 18

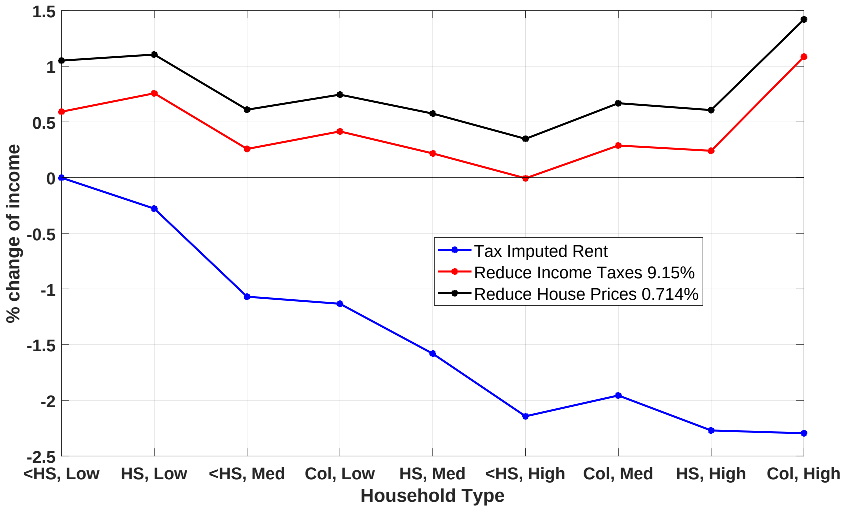
[35]This is a steady state analysis where all households are born into a world with taxation of imputed rent. Hence, we do not consider costs of converting an existing housing stock to the new demand patterns, such as converting some owner-occupied housing to rental property.

7.5.2 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 the distortions that: (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 3 plots the change 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 impact of taxing imputed rent while leaving the income tax and house price unchanged. Note that type 1s are essentially 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.

Figure 3: Welfare Impacts: Tax on Net Imputed Rent



However, a tax on imputed rent would finance a 9.15% cut in income tax rates. In a balanced revenue simulation, shown by the red line in Figure 3, 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. This still understates the welfare improvement, as the price of housing drops by 0.714% in equilibrium. The black line in Figure 3 factors in this additional benefit. Now taxing net imputed rent makes *every* type better off ex ante, including type 6, whose welfare improvement 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).

[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.

In the Appendix we report 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). 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.

Several caveats are notable: First, this is a steady state analysis where all households are born into a world with taxation of imputed rent. If the policy were implemented in real time, households that already have substantial home equity may be worse off. To avoid this, a tax on imputed rent could be grandfathered in. Second, in our model agents enter the first decision period at age 26 with no assets. An agent who inherits substantial assets could be made worse off. Third, a tax on imputed rent reduces the overall ownership rate by 4.9 pp in the new equilibrium, with large effects for low-income types. The key justification for tax preferences on owner-occupied housing is that ownership may create positive externalities. These may justify the policy *if they exist*. On the other hand, our model also 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 practical problem of measuring the imputed rent so it can be taxed.

7.6 Experiment 2: Eliminate Mortgage Interest Deduction

Before we consider eliminating MID, we report an experiment where it applies to real rather than nominal interest. The high nominal rates in the 70s and 80s made the MID very generous, creating an incentive to own. In the experiment, shown in Table 21 column 2, the ownership rate drops from 64.9% to 63.5%, a 2.2% decline. Average owner-occupied house size drops from 3.210 to 3.135, a 2.3% decline. So overall demand for owner-occupied housing drops by 4.4%. The drop in ownership is greatest at ages 36-45, which corresponds to 1978-87, roughly the peak interest rate period. In Figure A1 we see the value of the itemized relative to the standard deduction was highest in this period, but it has plunged in more recent years, as has the itemization rate. Interestingly, the landlord rate increases from 21.5% to 22.7%. So while people reduce their consumption of owner-occupied housing, their exposure to housing as an asset class declines only slightly.

Table 21 column 3 shows an experiment where we eliminate the MID, while holding income tax rates and house prices fixed. The effects are similar to making MID apply only to real interest. 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.

As we see in Table 22, eliminating the MID causes the ownership rate to drop by 2.4%, 2.3% and 1.3% for <HS, HS and college households respectively, while causing average

Table 21: Experiment: Remove Mortgage Interest Deduction (MID)

	Baseline (1)	Real Interest (2)	Remove MID (3)	Revenue Neutral (4)	Equilibrium Price (5)
Ownership Rate	0.649	0.635	0.635	0.636	0.643
Average Home Sizes					
All People	2.801	2.744	2.725	2.733	2.754
Owners	3.210	3.135	3.104	3.112	3.128
Renters	2.097	2.108	2.107	2.112	2.122
Ownership Rate by Age					
Age 26-35	0.435	0.428	0.426	0.429	0.439
Age 36-45	0.678	0.656	0.659	0.658	0.666
Age 46-55	0.719	0.704	0.704	0.705	0.708
Age 56-65	0.721	0.712	0.712	0.713	0.722
Age 66-77	0.712	0.705	0.704	0.707	0.715
Landlord Rate	0.215	0.227	0.235	0.234	0.243

Notes: (1) Baseline model, (2) MID applies to real interest, (3) Remove mortgage interest deduction, (4) Same as 3 but reduce income tax rates by 4.70%, (5) Same as 4 but reduce house price by 1.662% to equate supply and demand (tax rate is reduced 4.74%).

owner-occupied house size to drop by 4.1%, 3.3% and 2.8%, respectively. Thus, perhaps surprisingly, we see smaller proportional effects on both margins for the households with college educated heads. 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. On the other hand, as we saw in Sections 7.2 and 7.3, both income and price elasticities of demand for housing are much greater for lower income households.

Table 23 sheds more light on this issue. As we see, eliminating the MID has a negligible effect on the ownership rate of relatively high income households, types 6 through 9. But eliminating the MID does cause these households to buy smaller houses. On the other hand, eliminating the MID causes noticeable declines in the ownership rate for the low and middle income household 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. Eliminating the MID causes average owner-occupied house size to drop by 5.6%, 4.7%, 4.2% and 2.2% for types 6 through 9, respectively. In absolute terms the 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 4 of Table 21. As we have already seen, a tax cut has little effect on the ownership rate, but it does increase the average house size. 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%.

Table 22: Remove MID, Results by Education

	Baseline (1)	Real Interest (2)	Remove MID (3)	Revenue Neutral (4)	Equilibrium Price (5)
<High School					
Ownership Rate	0.456	0.445	0.445	0.446	0.454
Home size-All	2.365	2.316	2.306	2.314	2.335
Home size-Owners	2.968	2.869	2.845	2.854	2.871
High School					
Ownership Rate	0.707	0.690	0.691	0.691	0.699
Home size-All	2.864	2.803	2.784	2.792	2.814
Home size-Owners	3.134	3.061	3.032	3.041	3.059
College					
Ownership Rate	0.840	0.829	0.829	0.831	0.836
Home size-All	3.437	3.376	3.341	3.349	3.367
Home size-Owners	3.640	3.579	3.537	3.541	3.556

Notes. See notes for the Table 21.

Figure 4: Welfare Impacts: Remove Mortgage Interest Deduction

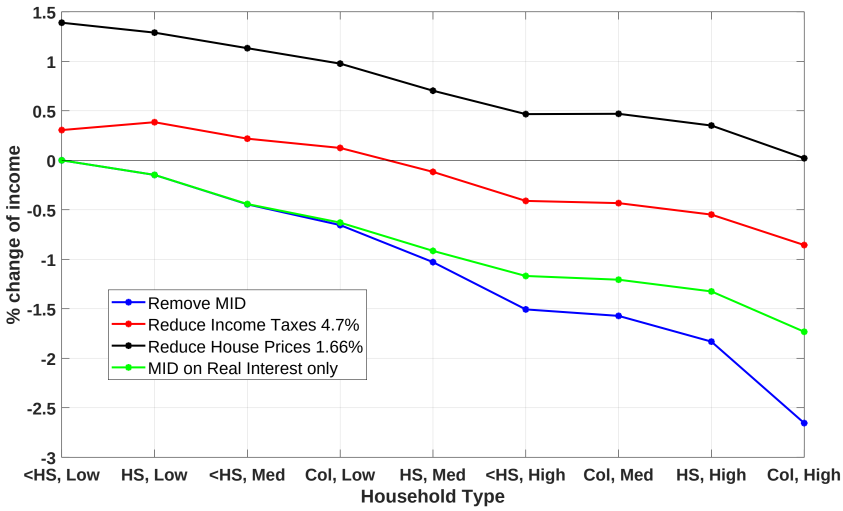


Figure 4 shows welfare impacts. Removing MID with taxes and prices fixed (black line) has no effect on type 1s, who almost never own. The impact is increasing with income, and for type 9s we have a loss equivalent to 2.7% of lifetime income.[37,38] When we also reduce income tax rates by 4.7% in the 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

[37]Note that mortgage rates were very high in the 70s, 80s and early 90s, when this cohort was about 26 to 50, so the MID was quite valuable for high income households. These years are heavily weighted in the present value calculations, as they are in the first half of the economic life-cycle.

[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 is about 600 dollars.

Table 23: Remove MID, Results by Type

	Baseline (1)	Real Interest. (2)	Remove MID (3)	Revenue Neutral (4)	Equilibrium Price (5)
1. <HS, Low					
Ownership Rate	0.001	0.001	0.001	0.001	0.002
Home Size - All	1.547	1.547	1.547	1.553	1.578
Home Size - Owners	1	1	1	1	1
2. HS, Low					
Ownership Rate	0.405	0.381	0.381	0.378	0.390
Home Size - All	2.033	2.036	2.036	2.044	2.061
Home Size - Owners	1.916	1.914	1.914	1.916	1.946
3. <HS, Med					
Ownership Rate	0.484	0.453	0.452	0.455	0.468
Home Size - All	2.315	2.298	2.298	2.301	2.323
Home Size - Owners	2.337	2.295	2.295	2.296	2.328
4. Col, Low					
Ownership Rate	0.639	0.612	0.608	0.611	0.621
Home Size - All	2.668	2.621	2.617	2.625	2.646
Home Size - Owners	2.829	2.765	2.76	2.764	2.790
5. HS, Med					
Ownership Rate	0.768	0.742	0.741	0.744	0.753
Home Size - All	2.876	2.792	2.781	2.789	2.815
Home Size - Owners	2.985	2.88	2.865	2.872	2.900
6. <HS, High					
Ownership Rate	0.880	0.878	0.879	0.881	0.890
Home Size - All	3.232	3.100	3.069	3.083	3.100
Home Size - Owners	3.319	3.169	3.133	3.148	3.163
7. Col, Med					
Ownership Rate	0.897	0.894	0.899	0.900	0.903
Home Size - All	3.443	3.353	3.295	3.305	3.332
Home Size - Owners	3.554	3.454	3.387	3.396	3.423
8. HS, High					
Ownership Rate	0.945	0.945	0.947	0.948	0.950
Home Size - All	3.678	3.578	3.530	3.541	3.562
Home Size - Owners	3.745	3.640	3.587	3.597	3.617
9. Col, High					
Ownership Rate	0.974	0.974	0.973	0.974	0.975
Home Size - All	4.155	4.109	4.066	4.070	4.078
Home Size - Owners	4.199	4.152	4.108	4.112	4.118

Notes.See notes for Table 21.

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.[39]

However, when MID is eliminated the price of housing falls 1.66% in equilibrium. We report these results in column 5 of Table 21, and the black line in Figure 4. Factoring in the price drop, the ownership rate only drops 0.6 pp, and all types are better off, 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.

[39]Comparing Figures 3 and 4, we see that taxing imputed rent reduces welfare of type 9s by 2.3% of lifetime income, while eliminating MID reduces it by 2.7%. So effects are comparable. The big difference is that when MID is eliminated they only get a 4.7% tax cut, but when imputed rent is taxed they get a much larger 9.15% tax cut. Mechanically, that explains why type 9s are better of with taxation of imputed rent but not with eliminating MID (in the fixed price experiment).

7.7 Experiment 3: Convert the MID into a Refundable Credit

As we saw Section 7.6 the MID played a valuable role in making ownership more affordable for low to middle income households, but for high income households it only encouraged larger house sizes. We also saw the MID is regressive, as it leads to transfers of wealth from poorer to wealthier households once the income tax needed to finance it is factored in. Several authors have advocated converting the MID into a "fully refundable" tax credit so it will provide greater benefits to lower income households (e.g., Dreier 1997, Green and Vandell 1999, Hanson et al. 2014, Drukker 2021). A credit is "fully refundable" if the amount of credit a household receives does not depend on the level of tax they owe.

In order to replace the MID with a refundable credit we must first decide the level of the credit. We determined that a 24.6% credit would be revenue neutral. This means households who faced a marginal income tax rate higher than 24.6% will be worse off with the refundable credit, while those who faced a marginal rate of less than 24.6%, or who owed no tax at all, will be better off.

Table 24 column 2 shows the impact of replacing the MID with the 24.6% refundable mortgage interest credit. This has clear positive effects on home ownership: the ownership rate increases 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%, an 7.6% increase. Effects are also greater for lower education households: As we see in Table 25, the increases are 2.6pp (5.7%) for the <HS type, 4.7pp (6.6%) for the HS type and only 0.9pp (1.1%) for the college type.

Table 24: Experiments: Refundable Mortgage Interest Tax Credit

		Mortgage Credit - 24.6%		Choose MID or Credit		
	Baseline (1)	Rev. Neutral (2)	Equilibrium (3)	Partial Eq. (4)	Rev. Neutral (5)	Equilibrium (6)
Ownership Rate	0.649	0.682	0.687	0.684	0.684	0.685
Average Home Sizes						
All People	2.801	2.747	2.765	2.797	2.793	2.796
Owners	3.210	3.076	3.092	3.150	3.146	3.147
Renters	2.097	2.085	2.092	2.084	2.081	2.082
Ownership Rate by Age						
Age 26-35	0.435	0.468	0.477	0.467	0.466	0.467
Age 36-45	0.678	0.704	0.707	0.704	0.704	0.705
Age 46-55	0.719	0.750	0.752	0.753	0.754	0.755
Age 56-65	0.721	0.771	0.775	0.774	0.775	0.776
Age 66-77	0.712	0.763	0.772	0.765	0.765	0.767
Landlord Rate	0.215	0.232	0.238	0.213	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) Allow households to choose between MID and the 24.6% credit, (5) Same as 4 but increase income tax rates by 2.75% to achieve revenue neutrality, (6) Same as 5 but price is reduced 0.18% that equates the demand and supply.

As we see in Table 26, the large positive effects on ownership are heavily concentrated on the low income types 2 and 3. The type 2s ownership rate increases from 40.5% to

Table 25: Refundable Tax Credit, Results by Education

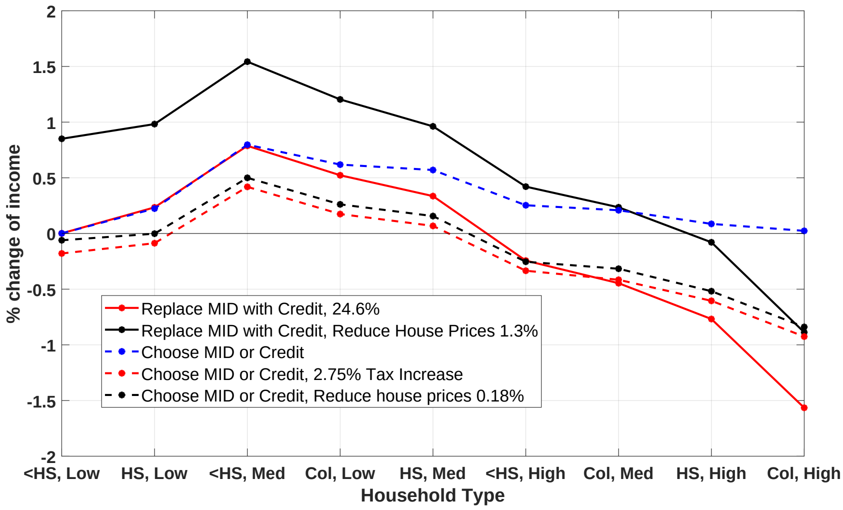
	Baseline (1)	Mortgage Credit: Rev. Neutral (2)	Mortgage Credit: Equilibrium (3)	Choose MID or Credit: Partial Eq. (4)	Choose MID or Credit: Rev. Neutral (5)	Choose MID or Credit: Equilibrium (6)
<High School						
Ownership Rate	0.456	0.482	0.489	0.484	0.484	0.485
Home size-All	2.365	2.331	2.345	2.363	2.361	2.366
Home size-Owners	2.968	2.856	2.864	2.922	2.922	2.928
High School						
Ownership Rate	0.707	0.754	0.758	0.755	0.755	0.756
Home size-All	2.864	2.801	2.820	2.857	2.852	2.853
Home size-Owners	3.134	2.985	3.004	3.061	3.055	3.055
College						
Ownership Rate	0.840	0.849	0.851	0.851	0.851	0.851
Home size-All	3.437	3.371	3.392	3.436	3.435	3.436
Home size-Owners	3.640	3.547	3.566	3.622	3.620	3.621

Notes. See notes for the Table 24.

53.9%, and that of type 3s increases from 48.4% to 55.0%. There is also a small 2pp increase for type 4. Types 5 through 9 are little affected. Thus, the refundable credit seems to be a very effective way to make ownership more affordable for low income types.

Interestingly, 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.[40] This is driven by relatively wealthy households shifting to smaller house sizes, as their after tax interest payments increase (As we see in Table 26, 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). The fraction of households that hold investment property increases by 1.7pp as agents seek to maintain exposure to housing as an asset class.

Figure 5: Welfare Impacts: Refundable Tax Credit



The red line in Figure 5 shows welfare impacts of replacing MID with a credit, with prices fixed. Welfare increases substantially for types 2 to 5, but falls for types 6 to 9.

[40]Recall that eliminating MID and giving a 4.7% tax cut reduced demand for housing by 2.4%, so we have a similar effect size here.

Table 26: Refundable Tax Credit, Results by Type

		Mortgage Credit		MID or Credit		
	Baseline (1)	Rev. Neutral (2)	Equilibrium (3)	Partial. (4)	Rev. Neutral (5)	Equilibrium (6)
1. <HS, Low						
Ownership Rate	0.001	0.002	0.003	0.002	0.002	0.002
Home Size - All	1.547	1.546	1.565	1.546	1.542	1.545
Home Size - Owners	1	1	1	1	1	1
2. HS, Low						
Ownership Rate	0.405	0.539	0.543	0.537	0.539	0.541
Home Size - All	2.033	2.002	2.027	2.007	2.003	2.005
Home Size - Owners	1.916	1.915	1.951	1.923	1.918	1.922
3. <HS, Med						
Ownership Rate	0.484	0.550	0.562	0.558	0.559	0.560
Home Size - All	2.315	2.324	2.340	2.326	2.324	2.328
Home Size - Owners	2.337	2.342	2.363	2.346	2.346	2.350
4. Col, Low						
Ownership Rate	0.639	0.659	0.662	0.669	0.670	0.671
Home Size - All	2.668	2.656	2.678	2.671	2.667	2.667
Home Size - Owners	2.829	2.795	2.819	2.814	2.809	2.807
5. HS, Med						
Ownership Rate	0.768	0.771	0.777	0.780	0.780	0.781
Home Size - All	2.876	2.827	2.843	2.879	2.872	2.875
Home Size - Owners	2.985	2.912	2.930	2.978	2.970	2.973
6. <HS, High						
Ownership Rate	0.880	0.891	0.896	0.886	0.886	0.887
Home Size - All	3.232	3.117	3.125	3.213	3.213	3.220
Home Size - Owners	3.319	3.181	3.188	3.293	3.293	3.301
7. Col, Med						
Ownership Rate	0.897	0.906	0.909	0.900	0.900	0.901
Home Size - All	3.443	3.326	3.360	3.439	3.436	3.438
Home Size - Owners	3.554	3.414	3.450	3.544	3.542	3.544
8. HS, High						
Ownership Rate	0.945	0.950	0.952	0.946	0.946	0.946
Home Size - All	3.678	3.568	3.587	3.680	3.675	3.674
Home Size - Owners	3.745	3.622	3.641	3.746	3.742	3.740
9. Col, High						
Ownership Rate	0.974	0.975	0.976	0.975	0.975	0.975
Home Size - All	4.155	4.086	4.094	4.153	4.155	4.158
Home Size - Owners	4.199	4.126	4.132	4.196	4.198	4.200

Notes. See notes for Table 24.

So there are winners and losers, but, as expected, a refundable credit is more progressive than the MID. However, as average house size falls, a shift from MID to a credit causes the aggregate demand for housing to fall. This causes house price to drop 1.3% in the new equilibrium. As we see in Table 24 column 2, this increases the ownership rate further to 68.7%, and that of young households increases to 47.7%. Welfare impacts are shown by the solid black line in Figure 5. The average welfare gain is equivalent to 0.71% 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 5 bracket welfare changes in the unit and infinitely elastic supply cases.)

We have seen 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.

7.7.1 Choice of MID or Credit

An alternative policy designed with the intention of reducing losses for high income types is to give households a choice between the MID and taking the 24.6% refundable credit. High income households can then 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 24 column 5, this 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 6, price drops by 0.18%.

The blue line in Figure 5 shows welfare impacts of this policy, while holding tax rates and prices fixed. It has no effect on type 1s, who almost never own a house, or on the type 9s, who always chose the MID, just as they do in the baseline. But type 2 through 8 are all better off, as the refundable credit is at least sometimes better for all these types.

However, the dotted black line shows the impacts of the 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 0.21% 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) that a 2.75% tax increase is required to finance it, and (ii) it does not generate a significant drop in the equilibrium house price. And that is because it does not remove the incentive for high income households to buy larger houses.

8 Conclusions

We have developed and estimated a dynamic life-cycle model of consumption and portfolio choice, including decisions about home ownership and investment property. Our model extends prior work in several important dimensions: By including investment property we allow demand for housing as an asset class to exceed the demand for housing as a consumption good. We incorporate house price uncertainty and risky capital gains on housing. We model both downpayment constraints and payment-to-income (PTI) constraints on mortgage loan qualification. We model changes in the tax structure from 1968 to 2019 in detail, and allow the agents in our model to choose between itemized and standard deductions. And we include important life-cycle features, including heterogeneous life-cycle earnings profiles, and household demand for housing that varies with age and presence of children. Our model allows us to assess the impact of favourable tax treatment of owner-occupied housing on ownership of both homes and investment property, home size, mortgage debt, financial assets and consumption.

We highlight three main findings: First, the favorable tax treatment of housing creates an economic inefficiency that we quantify. Taxing the net imputed rent on owner-occupied housing would raise enough revenue to finance an 9.15% cut in income tax rates, and lead to an 0.71% drop in house prices in equilibrium. The ownership rate would decline from 64.9% to 60.0%, with declines concentrated among low and middle income households and older households. But overall demand for housing in the economy drops very slightly, as demand simply shifts from owner-occupied property to rentals. All types of households would be ex ante better off if they were born into such a world, giving a Pareto improvement. The average welfare gain is equivalent to 0.79% of lifetime income.[41]

Second, the mortgage interest deduction in conjunction with progressive taxes encourages wealthier households to buy larger houses, with little effect on their tenure choices. Eliminating MID raises enough revenue to finance an 4.7% cut in income tax rates, and leads to an 1.66% drop in house prices in equilibrium. The ownership rate declines only slightly from 64.9% to 64.3%, but high income households buy smaller houses. All types of households would be ex ante better off if they were born into such a world, giving a Pareto improvement. The average welfare gain is equivalent to 0.76% of lifetime income.

Third, we find that a refundable mortgage interest credit, which generates payments even to households that do not itemize, would substantially improve housing affordability for low to middle income households – without the need to increase income taxes and without driving up house prices. We find the MID could be replaced with a 24.6% fully refundable credit in a budget neutral simulation. This reduces aggregate demand for housing, as high income households buy smaller houses, leading to a 1.3% price drop. However, the home ownership rate increases substantially, from 64.9% to 68.5%, with the gains concentrated among low and middle-income households. The average welfare gain is 0.58% of lifetime income. These gains are concentrated among low to middle-income households, while the wealthiest households are slightly worse off. So in contrast to the MID, the mortgage interest credit is a progressive program.

Unlike Berkovec and Fullerton (1992), Chambers et al. (2009b) and Sommer and Sullivan (2018), our model does not predict that taxing imputed rent or eliminating the MID would actually *increase* ownership (due to a combination of tax and price reductions), as our model predicts these tax changes would reduce the ownership rate by 5.3pp and 1.3pp, respectively, in revenue neutral simulations.[42] But neither do we predict *very large* negative effects, as in Gervais (2002), Cho and Francis (2011) and Floetotto et al. (2016). Interestingly, our results are actually closer to the earlier regression based studies

[41] Our model fails to capture positive externalities from home ownership, which may still justify the non-taxation of imputed rent. But it also fails to capture the positive impact of tax cuts on labor supply and human capital accumulation, which are added benefits of taxing imputed rent.

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

reviewed in Rosen (1985) which typically predict modest negative effects rather similar to our model predictions.

Of the policies we analyze, only a refundable mortgage interest credit increases home ownership, especially for low and middle-income households and young households. These may be important policy goals in themselves. Replacing MID with a credit would transfer welfare from the highest income to low and middle-income households, so it is not Pareto improving. However, high income households receive disproportionate benefits from tax preferences in the baseline system, so a policy to rectify this may in fact be desirable. Ours is the first paper to simulate the impact of a refundable credit in a dynamic model.

We conclude by highlighting a limitation of our analysis: All our experiments assess impacts on cohorts born into a new policy environment. This should be viewed as 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 the policy changes.) 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. 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, and (iii) fitting the model to detailed micro data rather than a small set of aggregate statistics.

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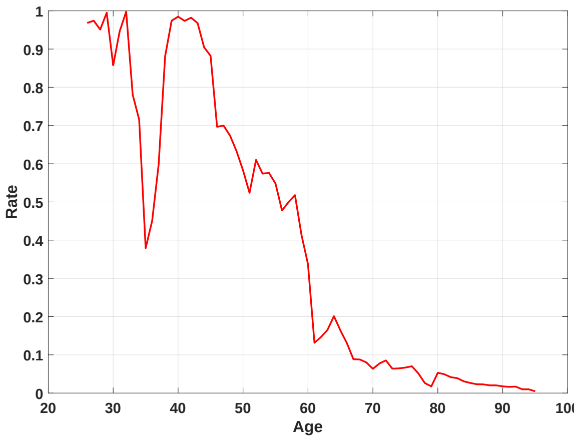
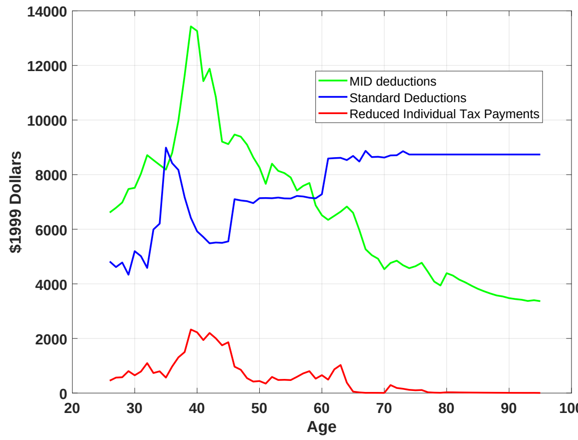
Appendices

A Additional Results

A1: Itemization Rate: Value of Itemized vs. Standard Deduction

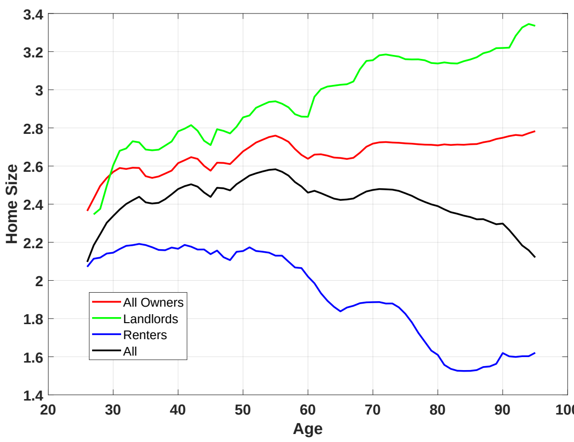


(a) Itemization Rate

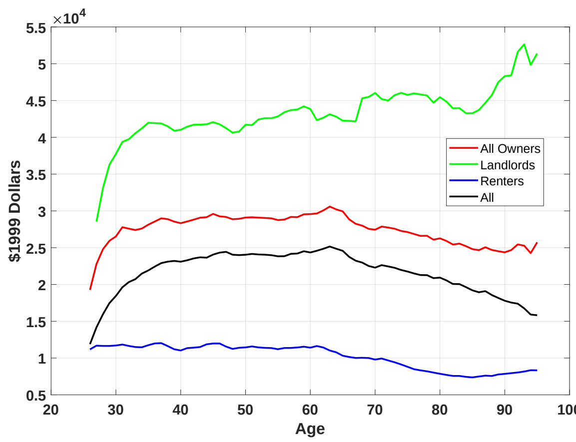


(b) MID vs. Standard Deduction

A2: Consumption over the Life-Cycle

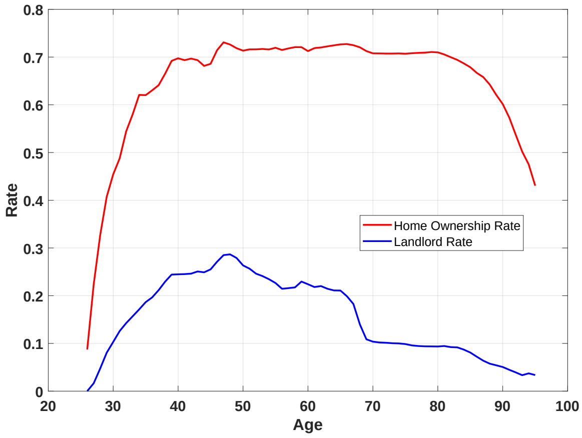


(a) Home Size

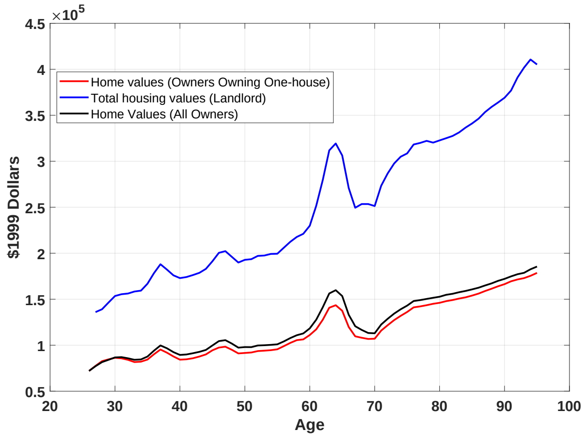


(b) Non-Housing Consumption

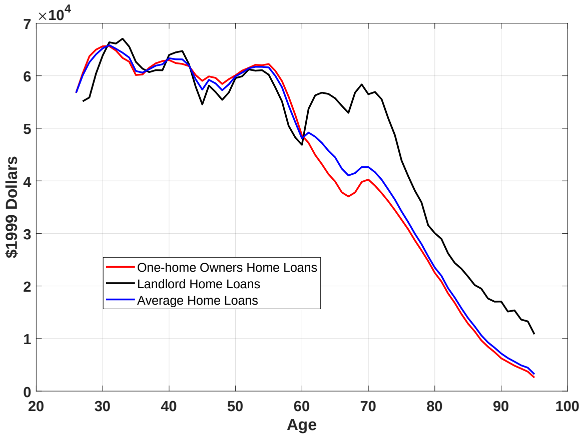
A3: Ownership Rate and Financial Variables over Life-Cycle: Baseline Model



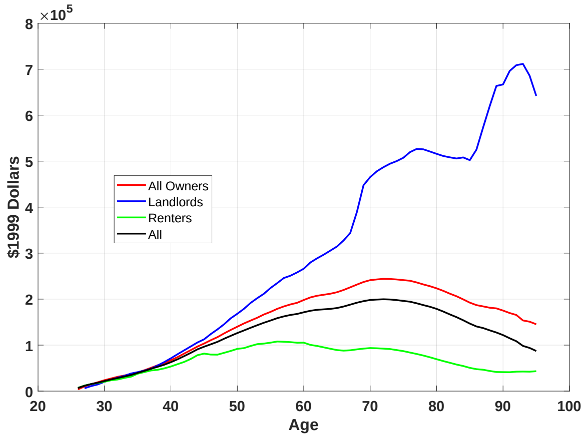
(a) Home Ownership Rate



(b) Home value



(c) Home Loans



(d) Financial Assets

Table A1: Tax Net Imputed Rent + Remove Mortgage Interest Deduction

	Baseline (1)	Partial Equilibrium (2)	Revenue Neutral (3)	Equilibrium Price (4)
Ownership Rate	0.649	0.573	0.585	0.597
Average Home Sizes				
All People	2.801	2.687	2.716	2.739
Owners	3.210	3.112	3.137	3.147
Renters	2.097	2.144	2.152	2.164
Ownership Rate by Age				
Age 26-35	0.435	0.404	0.414	0.427
Age 36-45	0.678	0.604	0.613	0.625
Age 46-55	0.719	0.626	0.639	0.648
Age 56-65	0.721	0.621	0.637	0.653
Age 66-77	0.712	0.622	0.640	0.653
Landlord Rate	0.215	0.220	0.220	0.232

Notes: (1) Baseline model, (2) Tax net imputed rent from owner-occupied housing, while also eliminating itemized deductions for mortgage interest and property tax, (3) Same as 3 but reduce income tax rates by 13% to achieve revenue neutrality, (4) Same as 3 but reduce house price by 2.2% to equate supply and demand.

Table A2: Tax Net Imputed Rent + Remove Mortgage Interest Deduction, by Education

	Baseline (1)	Partial Equilibrium (2)	Revenue Neutral (3)	Equilibrium Price (4)
<High School				
Ownership Rate	0.456	0.390	0.400	0.411
Landlord Rate	0.091	0.095	0.096	0.11
Home size-All	2.365	2.271	2.297	2.318
Home size-Owners	2.968	2.815	2.848	2.855
High School				
Ownership Rate	0.707	0.616	0.630	0.643
Landlord Rate	0.220	0.225	0.226	0.238
Home size-All	2.864	2.747	2.777	2.802
Home size-Owners	3.134	3.053	3.078	3.092
College				
Ownership Rate	0.840	0.793	0.803	0.811
Landlord Rate	0.432	0.440	0.434	0.446
Home size-All	3.437	3.293	3.323	3.342
Home size-Owners	3.640	3.521	3.541	3.552

Note: See notes for Table A1.

A4: Welfare Impacts: Tax Net Imputed Rent + Remove Mortgage Interest Deduction

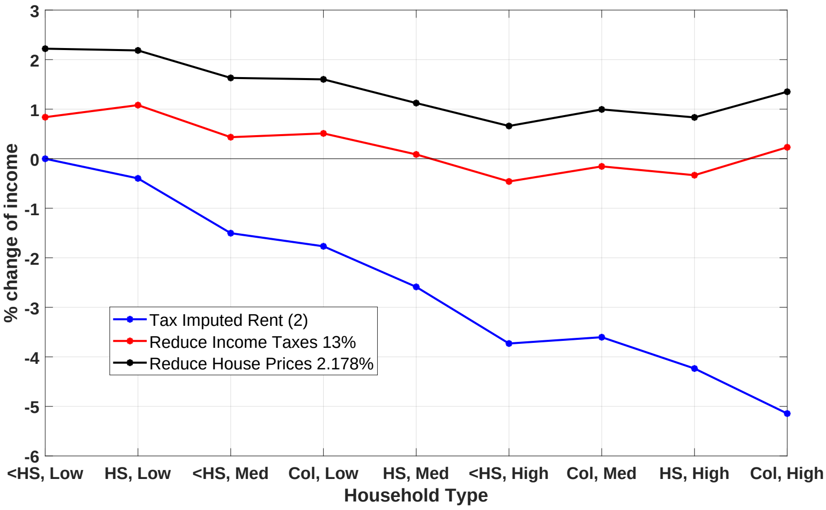


Table A3: Tax Net Imputed Rent and Remove Mortgage Interest Deduction, by Type

	Baseline (1)	Partial Equilibrium (2)	Revenue Neutral (3)	Equilibrium Price (4)
1. <HS, Low				
Ownership Rate	0.001	0.001	0.001	0.001
Home Size - All	1.547	1.547	1.564	1.596
Home Size - Owners	1	1	1	1
2. HS, Low				
Ownership Rate	0.405	0.255	0.269	0.286
Home Size - All	2.033	2.052	2.065	2.088
Home Size - Owners	1.916	1.867	1.884	1.921
3. <HS, Med				
Ownership Rate	0.484	0.336	0.353	0.373
Home Size - All	2.315	2.276	2.295	2.312
Home Size - Owners	2.337	2.229	2.256	2.287
4. Col, Low				
Ownership Rate	0.639	0.518	0.544	0.557
Home Size - All	2.668	2.551	2.576	2.602
Home Size - Owners	2.829	2.682	2.704	2.732
5. HS, Med				
Ownership Rate	0.768	0.655	0.677	0.696
Home Size - All	2.876	2.713	2.752	2.768
Home Size - Owners	2.985	2.798	2.837	2.849
6. <HS, High				
Ownership Rate	0.880	0.834	0.846	0.859
Home Size - All	3.232	2.985	3.029	3.042
Home Size - Owners	3.319	3.052	3.097	3.105
7. Col, Med				
Ownership Rate	0.897	0.880	0.885	0.893
Home Size - All	3.443	3.249	3.293	3.314
Home Size - Owners	3.554	3.345	3.390	3.407
8. HS, High				
Ownership Rate	0.945	0.935	0.940	0.944
Home Size - All	3.678	3.473	3.512	3.549
Home Size - Owners	3.745	3.534	3.571	3.607
9. Col, High				
Ownership Rate	0.974	0.970	0.972	0.973
Home Size - All	4.155	4.032	4.054	4.064
Home Size - Owners	4.199	4.078	4.097	4.104

Note: See notes for Table A1

B Data

Table B4: Case-Schiller House Price index (CS HPI)

AGE	Date	Nominal CS HPI	CPI 1999 dollars	Real HPI 1999 dollars	Real HPI Growth Rate
26	1968	17.032	0.208	0.851	
27	1969	18.139	0.217	0.868	0.020
28	1970	19.595	0.230	0.883	0.017
29	1971	20.677	0.242	0.885	0.002
30	1972	21.532	0.250	0.893	0.008
31	1973	21.979	0.259	0.879	-0.015
32	1974	23.635	0.284	0.864	-0.017
33	1975	25.736	0.317	0.842	-0.026
34	1976	27.607	0.338	0.846	0.005
35	1977	30.918	0.356	0.901	0.064
36	1978	35.615	0.380	0.971	0.078
37	1979	41.094	0.416	1.025	0.056
38	1980	45.093	0.474	0.988	-0.037
39	1981	47.959	0.530	0.940	-0.049
40	1982	48.951	0.574	0.885	-0.058
41	1983	50.462	0.595	0.879	-0.006
42	1984	52.841	0.620	0.884	0.005
43	1985	55.888	0.642	0.903	0.022
44	1986	60.827	0.667	0.946	0.048
45	1987	66.275	0.677	1.016	0.074
46	1988	71.151	0.704	1.048	0.032
47	1989	75.513	0.737	1.063	0.014
48	1990	76.937	0.775	1.029	-0.032
49	1991	75.922	0.819	0.961	-0.066
50	1992	76.329	0.841	0.942	-0.020
51	1993	77.418	0.868	0.925	-0.018
52	1994	79.477	0.890	0.926	0.001
53	1995	81.008	0.915	0.919	-0.009
54	1996	82.833	0.940	0.914	-0.005
55	1997	85.346	0.968	0.914	0.000
56	1998	90.128	0.984	0.951	0.040
57	1999	96.403	1.000	1.000	0.052
58	2000	104.777	1.027	1.058	0.058
59	2001	113.187	1.066	1.102	0.041
60	2002	122.288	1.078	1.177	0.068
61	2003	133.743	1.106	1.254	0.066
62	2004	150.466	1.127	1.385	0.104
63	2005	171.782	1.161	1.535	0.109
64	2006	183.488	1.207	1.577	0.027
65	2007	179.951	1.232	1.515	-0.039
66	2008	164.069	1.285	1.324	-0.126
67	2009	148.560	1.285	1.199	-0.094
68	2010	144.661	1.319	1.138	-0.051
69	2011	139.238	1.340	1.078	-0.053
70	2012	140.995	1.380	1.060	-0.016
71	2013	154.532	1.402	1.144	0.079
72	2014	164.706	1.424	1.200	0.049
73	2015	172.221	1.422	1.256	0.047
74	2016	181.002	1.442	1.302	0.037
75	2017	191.556	1.478	1.344	0.032
76	2018	202.766	1.509	1.394	0.037
77	2019	204.708	1.532	1.386	-0.006
		Compound annual growth rate			
		5.1%	4.1%	1.0%	
Mean annual growth rate					0.0108
Median annual growth rate					0.0084
s.d					0.0486

Notes. The data is sourced from Shiller (2019).

Table B5: Data Explanation

Age	Group	Window	Time	Variables	Obs.
26	1	25-27	1968	1,2,3,4	304
27	1	26-28	1969	1,2,3,4,5	282
28	1	27-29	1970	1,2,3,4,5	291
29	1	28-30	1971	1,2,3,4,5	303
30	1	29-31	1972	1,2,3,4,5	299
31	1	30-32	1973	1,2,3,4	293
32	1	31-33	1974	1,2,3,4	299
33	1	32-34	1975	1,2,3,4	303
34	1	33-35	1976	1,2,3,4,5	295
35	2	34-36	1977	1,2,3,4,5	298
36	2	35-37	1978	1,2,3,4,5	306
37	2	36-38	1979	1,2,3,4,5	298
38	2	37-39	1980	1,2,3,4,5	291
39	2	38-40	1981	1,2,3,4,5	289
40	2	39-41	1982	1,2,3,4	291
41	2	40-42	1983	1,2,3,4,5	288
42	2	41-43	1984	1,2,3,4,5,6,7,8	282
43	2	42-44	1985	1,2,3,4,5	282
44	2	43-45	1986	1,2,3,4,5	276
45	3	44-46	1987	1,2,3,4,5	273
46	3	45-47	1988	1,2,3,4,5	276
47	3	46-48	1989	1,2,3,4,5,6,7,8	262
48	3	47-49	1990	1,2,3,4,5	397
49	3	48-50	1991	1,2,3,4,5	386
50	3	49-51	1992	1,2,3,4,5	376
51	3	50-52	1993	1,2,3,4,5	377
52	3	51-53	1994	1,2,3,4,5,6,7,8	282
53	3	52-54	1995	1,2,3,4,5	346
54	3	53-55	1996	1,2,3,4,5	259
55	4	54-56	1997	1,2,3,4,5	208
57	4	56-58	1999	1,2,3,4,5,6,7,8,9,10,11	197
59	4	58-60	2001	1,2,3,4,5,6,7,8,9,10,11	194
61	4	60-62	2003	1,2,3,4,5,6,7,8,9,10,11	195
63	4	62-64	2005	1,2,3,4,5,6,7,8,9,10,11	185
65	5	64-66	2007	1,2,3,4,5,6,7,8,9,10,11	178
67	5	66-68	2009	1,2,3,4,5,6,7,8,9,10,11	170
69	5	68-70	2011	1,2,3,4,5,6,7,8,9,10,11	166
71	5	70-72	2013	1,2,3,4,5,6,7,8,9,10,11	166
73	5	72-74	2015	1,2,3,4,5,6,7,8,9,10,11	208
75	5	74-76	2017	1,2,3,4,5,6,7,8,9,10,11	102
77	5	76-78	2019	1,2,3,4,5,6,7,8,9,10,11	122
All Ages					12,384

Notes. In the 5th column, 1-Total household Income, 2- The number of young kids, 3-House value, 4-The actual rooms,5- Loan of the owner-occupied home, 6-The equity of the other real estate, 7-Net worth, 8-Financial assets, 9-Housing expenditure, 10-Nonhousing expenditure, 11-Total expenditure

Table B6: A comparison of the expenditure between CES and PSID

	CES		PSID		Scaled up_ratio	
Time	Housing expenditure	Non-housing expenditure	Housing expenditure	Non-housing expenditure	Housing expenditure	Non-housing expenditure
1999	10059	26933	8976	15580	1.121	1.729
2001	10363	26709	9360	16414	1.107	1.627
2003	10314	26577	9313	16352	1.107	1.625
2005	11018	28957	12580	22538	0.876	1.285
2007	11757	28531	13204	21155	0.890	1.349
2009	11463	26720	12658	19334	0.906	1.382
2011	10948	26106	12079	18536	0.906	1.408
2013	10675	25779	11227	19222	0.951	1.341
2015	11203	28134	12371	20550	0.906	1.369
2017	11598	29024	11412	18354	1.016	1.581
2019	11480	29084	11970	18697	0.959	1.556

Notes. CES: The housing and nonhousing expenses are calculated as the average of the consumer units. Source of data: Table 1300. Age of reference person: Annual expenditure means, shares, standard errors, and coefficients of variation, Consumer Expenditure Survey, U.S. Bureau of Labor Statistics. PSID: The average of the expenses of all people observed in the survey year.

Table B7: Exemptions from taxable income

Date	Standard Deduction 1999 dollars	Personal and Dependents Exemption in 1999 dollars			Nominal interest
		married	single	per child	
1968	4818	5782	2891	2891	7.00
1969	4615	5538	2769	2769	7.00
1970	4781	5433	2717	2717	7.00
1971	4335	5573	2786	2786	7.54
1972	5197	5996	2998	2998	7.38
1973	5014	5785	2893	2893	8.04
1974	4583	5289	2644	2644	9.19
1975	5992	4730	2365	2365	9.05
1976	6206	4433	2216	2216	8.87
1977	8989	4213	2106	2106	8.85
1978	8421	3943	1972	1972	9.64
1979	8173	4811	2406	2406	11.20
1980	7173	4224	2112	2112	13.74
1981	6415	3777	1889	1889	16.63
1982	5923	3485	1742	1742	16.11
1983	5714	3360	1680	1680	13.24
1984	5484	3225	1612	1612	13.88
1985	5514	3239	1620	1620	12.43
1986	5502	3238	1619	1619	10.19
1987	5555	5615	2807	2807	10.21
1988	7100	5538	2769	2769	10.34
1989	7055	5427	2713	2713	10.32
1990	7029	5288	2644	2644	10.13
1991	6958	5249	2624	2624	9.25
1992	7138	5473	2736	2736	8.39
1993	7143	5415	2708	2708	7.31
1994	7136	5507	2753	2753	8.38
1995	7160	5466	2733	2733	7.93
1996	7130	5427	2714	2714	7.81
1997	7126	5473	2737	2737	7.60
1998	7219	5490	2745	2745	6.94
1999	7200	5500	2750	2750	7.43
2000	7154	5451	2725	2725	8.05
2001	7131	5348	2674	2674	6.97
2002	7283	5566	2783	2783	6.54
2003	8590	5516	2758	2758	5.83
2004	8605	5500	2750	2750	5.84
2005	8616	5342	2757	2757	5.87
2006	8534	5468	2734	2734	6.41
2007	8685	5520	2760	2760	6.34
2008	8480	5446	2723	2723	6.03
2009	8871	5680	2840	2840	5.04
2010	8644	5535	2768	2768	4.69
2011	8654	5521	2760	2760	4.45
2012	8626	5509	2754	2754	3.66
2013	8704	5565	2783	2783	3.98
2014	8710	5549	2774	2774	4.17
2015	8858	5624	2812	2812	3.85
2016	8738	5617	2809	2809	3.65
2017	8738	5480	2740	2740	3.99
2018	8738	5369	2685	2685	4.54
2019	8738	5287	2644	2644	3.94

Notes. The source of the code for the exemptions: http://www.taxpolicycenter.org/statistics/standard-deduction - standard deduction for 1989-1970. The nominal interest rates are sourced from Freddie Mac (2022).