Implications of U.S. Tax Policy for House Prices and Rents*

Kamila Sommer Paul Sullivan

Very Preliminary and Incomplete

February 2012

Abstract

This paper studies the impact of the preferential tax treatment of housing, including the mortgage interest deduction, on equilibrium house prices, rents, and homeownership using a dynamic stochastic life cycle model of housing choice. To analyze the effects of housing tax expenditures on equilibrium outcomes in the housing market, we build a model with a realistic tax system in which owner-occupied housing services are tax-exempt, and mortgage interest payments, property taxes, and landlord's business costs are tax deductible. We simulate the effect of various tax reform proposals on house prices, rents, homeownership, and tax revenue. Through these simulations, we find that when the housing supply is relatively inelastic, repealing exisiting tax deductions leads to a decline in house prices, and also increases the homeownership rate. This happens because deductions are capitalized into house prices, and higher prices crowd aspiring low wealth homeowners out of the housing market. Our results challenge the widely held view that the mortgage interest tax deduction promotes homeownership. Moreover, repealing deductions leads to an increase in income tax revenue through increases in taxable income, but property tax revenue falls as house prices decline.

*Contact information: Sommer (kv28@georgetown.edu), Sullivan (pauljsullivan@gmail.com)

1 Introduction

Housing is the single-most important asset for the vast majority of U.S. households. The market value of the housing stock in the United States was estimated at $24.1 trillion at the end of 2005: this figure is 1.42 times the combined capitalizations of the NYSE, Nasdaq and Amex stock exchanges (Davis and Heathcote (2007)). Because housing accounts for such a large fraction of national wealth, changes in house prices have important macroeconomic effects. The income tax provisions related to mortgage interest and property tax deductions were estimated to provide a $114 billion subsidy to homeowners just in the year 2011 (JTC, 2010). Therefore, federal income tax policy toward owner-occupied housing has first-order effects on housing consumption, homeownership, and housing values.

This paper studies the effects of the preferential tax treatment of housing and evaluates a number of proposed housing finance tax reforms using a dynamic equilibrium model of the housing market with endogenous house prices and rents. Existing studies of the tax treatment of housing have not allowed both house prices and rents to be endogenous (see, for example, Gervais (2002), Díaz and Luengo-Prado (2008), Nakajima (2010), and Chambers, Garriga and Schlagenhauf (2009a, 2009b, 2009c)). We demonstrate that because the U.S. tax code affects both the homeownership decisions of households and the rental property supply decisions of landlords, ignoring equilibrium effects can lead to misleading conclusions about the effects of tax policy on house prices, rents, housing consumption, and homeownership. We show that in equilibrium, when the housing supply is relatively inelastic and both house prices and rents are allowed to adjust, a reduction in the tax deductions available to homeowners leads to a sizable decline in house prices, lower rents, and perhaps surprisingly, increased homeownership. The intuition behind this result is that when the housing supply is relatively inelastic, housing subsidies are capitalized into house prices. As house prices increase, low wealth households are crowded out of the housing market because the minimum down payment required to purchase a house rises. Our findings stand in sharp contrast to the widely held view that the preferential tax treatment of housing always promotes homeownership. At the same time, this paper provides a quantitative theory which can explain the empirical results of Hilber and Turner (2010), who find evidence that preferential tax treatment of homeownership can in fact depress homeownership.[1]

[1] Hilber and Turner (2010) use the variation in mortgage interest deductions across time and states to

To study the effect of the U.S. tax code on housing market, we build a stochastic life cycle Aiyagari-Bewley-Huggett economy model with an explicit rental market and a market for homeownership. Building on the idea of houses as durable, lumpy consumption goods that provide shelter services and confer access to collateralized borrowing, but can also be used as rental investments, we endogenize the buy vs. rent decision and also allow homeowners to lease out their properties in the rental market. The supply of rental housing is thus determined endogenously within the model, as homeowners weigh their utility from shelter space against rental income, taking into account the tax implications of their decisions. Both house prices and rents are determined in equilibrium through the clearing of markets for rented and owned housing. Mortgages are available to finance purchases of housing, but home-buyers must satisfy a minimum down payment requirement, and moving is a subject to lumpy transaction costs. The model includes a realistic progressive tax system that mimics the U.S. tax code, including the itemized tax deductions available to homeowners and landlords that are important determinants of demand for housing and rental supply. More specifically, in the model economy, homeowners can reduce the cost of housing consumption by taking advantage of mortgage interest and property tax deductions, and imputed rents on owner occupied housing are not taxed. At the same time, landlords in the model must pay income taxes on rental income, but they are permitted to deduct operating expenses such as mortgage interest payments, property taxes, maintenance expenses, and depreciation allowances from their gross rental income.

Having estimated the economy to replicate a number of relevant cross-sectional and aggregate moments of the U.S. economy, we conduct a series of counterfactual experiments to quantify the effect of changes in the federal income tax treatment of housing on house prices, rents, and homeownership. In the first step, we assess the implications of eliminating the mortgage interest deduction, property tax deduction, and depreciation allowances available to landlords on the housing market equilibrium in a set up where our tax experiments are not revenue-neutral. In the second step, we extend our analysis with revenue-neutral experiments (to be completed). As discussed above, we find that eliminating mortgage interest or property tax deductions can promote homeownership through lowering of house prices. Rents falls as

estimate their effect on homeownership. The authors find that on average mortgage interest deductions lead to higher house prices and lower homeownership rates, as deductions are capitalized into house prices. The effect is particularly strong when housing supply is relatively inelastic.

exiting renters enter the housing market and the demand for rental space falls. Turning to depreciation allowances for landlords, extending the period over which a rental investment property can be depreciated from the current 27.5 years to 55 years leads to a reallocation of housing from the rental sector to owner-occupiers. As with the other deductions, depreciation allowances are capitalized into house prices. Lowering depreciation allowances increases cost of rental investment, effectively inducing landlords to partly sell their properties to renters and owner-occupiers for whom the tax treatment is unchanged. In equilibrium, reductions in depreciation allowances for landlords lead to lower house prices, lower rents, and higher homeownership, as renters enter homeownership and the demand for rental space decreases.

We also show that eliminating deductions can have an asymmetric effect on the ability to balance the budget by federal vs. state and local governments. From the federal perspective, eliminating deductions leads to increased income tax revenue, as taxable income rises. However, viewed through the lens of a local government, the house price decline associated with eliminating deductions leads to a decline in property tax revenue. In terms of income tax revenue, our analysis also highlights the key role that the house price level plays in determining the total value of mortgage interest and property tax expenditures in the economy. When mortgage interest deductions are eliminated, house prices fall, thus decreasing the value of property tax deductions. Conversely, when property tax deductions are eliminated, the corresponding fall in house prices implies that homeowners need less debt to finance housing consumption. The decline in household mortgage debt further increases taxable income as the value of mortgage interest deductions falls. Our results highlight how eliminating one housing subsidy also affects the total expenditure on the other subsidies.

The impact of tax housing tax policies on the housing market has been studied by many authors (for seminal studies, see Laidler (1962), Aaron (1972), and Rosen (1979)). Poterba (1984) argues that the tax provisions for mortgage interest deductibility, in tandem with rising inflation rates, could explain much of the run-up in house prices during the 1970s.[2] The author's results suggest that eliminating mortgage interest deductions is likely to lead a house price decline, but the size of the decline could be close to catastrophic when combined with a high inflation rate.[3] Poterba (1992) explores the tax subsidies for investing in rental

[2] When inflation rate is high, rising inflation rates push up nominal interest rates, increasing homeowners' interest charges. The author also investigates the effect of tax policy toward capital gains.

[3] Poterba (1984) estimates that for an economy with a constant 10 percent inflation rate and 25 percent marginal tax rate, eliminating mortgage interest deductions would lead to an immediate 26 percent decline

property. The author argues that a reduction in marginal tax rates following the 1980s tax reforms and the tax changes that reduced subsidies for investing in rental property (including the depreciation time horizon - examined here, as well as capital gains tax rates and the passive-loss provisions) lowered households' incentive to invest in rental properties, thus affecting the homeownership and investment decisions of millions of U.S. households. More recently, Gervais and Pandey (2008) use the Survey of Consumer Finances (SCF) to measure the change in federal tax liability that would result if mortgage interest was no longer deductible from taxable income. The authors argue that the elimination of mortgage tax deductions would lead households to re-shuffle balance sheets, lowering the amount of interest income taxes collected. In a similar vein, Poterba and Sinai (2011) use SCF data to analyze how several potential tax reforms could affect incentives for housing consumption as well as the distribution of income tax burdens. The authors estimate that repealing the mortgage interest rate deduction in 2003 would have raised income by $72.4 billion in absence of any portfolio adjustments, but by only $61.9 billion if homeowners responded by drawing down a limited set of financial assets to partially replace the mortgage debt. The above mentioned studies are unable to assess the effect of eliminating mortgage tax deductions on house prices, rents, housing consumption, or homeownership. We use our model to quantitatively study how all of these equilibrium outcomes respond to changes in the tax code.

Other authors have used theoretical dynamic models in the quantitative macroeconomic tradition to study these issues.[4] Gervais (2002) examines the taxation of housing in the context of a dynamic life-cycle economy with housing rental services provided by a rental firm, where the house price is normalized at unity. Contrary to this paper, the author finds that the mortgage interest deduction leads to a decline in homeownership. Gervais's results highlight the key role that house price adjustments play in determining the response of homeownership to changes in the tax code. When house price level is fixed (as in Gervais (2002)), mortgage interest deductions reduce the cost of ownership but do not increase down payment requirements through their capitalization into house prices. When the user cost

in house prices.

[4]Berkovec and Fullerton (1992) employ a static disaggregated general equilibrium model to study the implications of tax policy for housing and portfolio choices. They find that when all the tax advantages to homeownership are disallowed, the total quantity of owner occupied housing consumption decreases, and so does the homeownership rate.

falls while house prices are unchanged, the homeownership rate rises. Our model shows that when house prices are allowed to adjust in response to elimination of mortgage interest deductions, the homeownership rate actually falls.

Chambers, Garriga, and Schlagenhauf (2009c) analyze the connection between the asymmetric tax treatment of homeowners and landlords and the progressivity of income taxation in a general equilibrium framework, where rents and interests rates - but not house prices - are determined endogenously. Our model builds on Chambers, Garriga and Schlagenhauf (2009a, 2009b, 2009c), who document that the majority of rental properties in the U.S. are owned by households, and then propose a framework for modeling the rental investment decisions of households. We extend their model by endogenizing both house prices and rents. Similarly to Chambers, Garriga, and Schlagenhauf (2009c), we find that eliminating the mortgage interest deduction has a positive effect on homeownership. However, the mechanism generating the increase in homeownership differs between the two papers. In Chambers, Garriga, and Schlagenhauf (2009c), the house price is fixed at unity, so the house price effect generated in our model is not operative. Instead, in their model under the assumption of revenue neutrality, eliminating the mortgage interest deduction lowers average tax rates in the economy, and leads to an increase in household income and wealth and lower interest rates. As income and wealth rise while the cost of financing falls and house prices are unchanged, marginal households move from renting to homeownership. Allowing house prices to adjust in equilibrium bolster these effects in our paper: both the house price and price-rent ratio fall, making homeownership more affordable relatively to renting. Homeownership rises, but lowered cost of housing consumption through the house price decline offsets the increase in cost caused by eliminating of deductions, and allows households to roughly maintain their current housing consumption.

Nakajima (2010) studies the optimal capital income taxation in a general equilibrium model with a representative rental firm ala Gervais (2002) that incorporates characteristics of housing and the U.S. preferential tax treatment of owner-occupied housing. As in Gervais (2002), house prices are normalized to one. Díaz and Luengo-Prado (2008) calculate the bias resulting from valuing owner-occupied housing services using the rental equivalence as opposed to user cost in a dynamic partial equilibrium model where both house prices and rents follow exogenous processes. The authors find that the tax exemption of owner-occupied housing services is the most important factor that distorts the rental price and the user cost of housing. Our model of the housing market incorporates this important wedge.

This paper is organized as follows. In Section 2, we develop a quantitatively rich stochastic life cycle model of the housing market with fully specified household choices with respect to consumption, saving, and homeownership, and provide the rationale for our modeling assumptions. Section 3 defines the equilibrium of the economy, while Section 4 describes the model's estimation. Section 5 discusses the fit of the benchmark model. In Section 6, we conduct a series of counterfactual tax-policy experiments that are targeted at assessing the effect of reducing housing tax subsidies for homeowners and landlords on house prices, rents and homeownership. Section 7 concludes.

2 The Model Economy

We consider an Aiyagari-Bewley-Huggett style economy with heterogeneous households. Households derive utility from nondurable consumption and from shelter services which are obtained either via renting or through ownership. Households supply labor inelastically, receive an idiosyncratic uninsurable stream of earnings in the form of endowments, and make joint decisions about their consumption of nondurable goods and shelter services, house size, mortgage size, and holdings of deposits. Young households start their life cycle as renters with zero asset holdings and have limited access to credit because all borrowing in the model is tied to ownership of housing. Idiosyncratic earnings shocks can be partially insured through precautionary savings (deposits), or through collateralized borrowing in the form of liquid home equity lines of credit (HELOCs). Households prefer homeownership to renting, in part because of the tax advantages to homeownership embedded in the U.S. tax code, but may be forced to rent due to the down payment requirement and the financing cost of homeownership. Purchases and sales of housing are subject to transaction costs and the housing stock is subject to depreciation. An important feature of our model is that houses can be used as a rental investment: they provide a source of income when leased out, and tax deductions available to landlords can be used to offset non-rental income and rental property related depreciation expenses. House prices and rents are determined in equilibrium through clearing of housing and rental markets.

2.1 Demography and Labor Income

The model economy is inhabited by a continuum of overlapping generations households with identical preferences. The model period is one year. Following Heathcote (2005) and Castaneda, Díaz-Gimenez, and Ríos-Rull (2003), we model the life cycle as a stochastic transition between various labor productivity states that also allows household's expected income to rise over time. The stochastic-aging economy is designed to capture the idea that liquidity constraints may be most important for younger individuals who are at the bottom of an upward-sloping lifetime labor income profile without requiring that household age be incorporated into our already large state space.

In our stochastic life cycle model, households transit from state w via two mechanisms: (i) aging and (ii) productivity shocks, where the events of aging and receiving productivity shocks are assumed to be mutually exclusive. The probability of transiting from a state w_j via aging is equal to $\phi_j = 1/(p_j L)$, where p_j is the fraction of population with productivity w_j in the ergodic distribution over the discrete support $\mathcal{W}$, and L is a constant equal to the expected lifetime. Similarly, the conditional probability of transiting from a working-age state w_j to a working-age state w_i due to a productivity shock is defined as $P(w_i|w_j)$. The overall probability of moving from state j to state i, denoted by π_{ji}, is therefore equal to the probability of transition from j to i via aging, plus the probability of transition from j to i via a productivity shock, conditional on not aging, so that

$$\Pi = \begin{bmatrix} 0 & \phi_1 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \phi_{J-1} \\ \phi_J & 0 & 0 & 0 \end{bmatrix} + \begin{bmatrix} (1-\phi_1) & 0 & 0 & 0 \\ 0 & \ddots & 0 & 0 \\ 0 & 0 & (1-\phi_{J-1}) & 0 \\ 0 & 0 & 0 & (1-\phi_J) \end{bmatrix} P. \tag{1}$$

The fractions p_j are the solutions to the system of equations $p = p\Pi$. A detailed description of this process is available in the Appendix of Heathcote's paper.

Young households are born as renters. In this model, we do not allow for inter-generational transfers of wealth (financial or non-financial) or human capital. Instead, we assume that, upon death, estates are taxed at a 100 percent rate by the government and immediately resold.

2.2 Preferences

Our model economy is inhabited by a continuum of households. Consistent with existing studies of the housing market, each household has a per-period utility function of the form:

$$U(c, s), \tag{2}$$

where c stands for nondurable consumption, and s represents the consumption of shelter services. Shelter services can be obtained either via the rental market at price ρ per unit or though homeownership at price q per unit of housing, h'. A linear technology is available that transforms one unit of housing stock, h', into one unit of shelter services, s. The household's choices about the amount of housing services consumed relative to the housing stock owned, $(h' - s)$, determine whether a household is renter $(h' = 0)$, owner-occupier $(h' = s)$, or landlord $(h' > s)$. Landlords lease $(h' - s) =: l$ to renters at rental rate ρ.

2.3 Assets and market arrangements

There are three assets in the economy: houses $(h \geq 0)$, deposits $(d \geq 0)$ with an interest rate r, and collateral debt $(m \geq 0)$ with a mortgage rate r^m. Households may alter their individual holdings of the assets h, d, and m to the new levels h', d', and m' at the beginning of the period after observing their within-period income shock w.

Houses are big items that are available in $K = 11$ discrete sizes, $h \in \{0, h(1), ..., h(K)\}$. Households may choose not to own a house $(h' = 0)$, in which case they obtain shelter through the rental market. Agents also make a discrete choice about shelter consumption. Households can rent a small unit of shelter, $\underline{s}$, which is smaller that than the minimum house size available for purchase, $\underline{s} < h(1)$. Renters are also free to rent a larger amount of shelter. To maintain symmetry between shelter sizes available to homeowners and renters, we assume that all levels of shelter consumption must match a point on the housing grid, so $s \in \{\underline{s}, h(1), ..., h(K)\}$. The total housing stock, H, is fully owned by households and its size does not change over time.[5] Our set-up with endogenous house prices and inflexible housing

[5] Although the stock of housing (as well as population size) is fixed in our model, there is evidence that the stock of housing increased over the boom period. For example, according to the National Income and Product Accounts (NIPA) tables, residential investment as a fraction of fixed investment hovered at about 15 percent between 1949 and 2000, while it rose from 18.2% to 25.2% between 2000 and 2005. However, section 5.4 of the paper demonstrates that the generated increase in the price-rent ratio in our model is robust to allowing for increases in the stock of housing.

supply thus represents an alternative to a production economy where land – the input factor into the housing production – is in fixed supply.

Houses are costly to buy and sell. Households pay a non-convex transactions costs of τ^b percent of the house value when buying a house, and pay τ^s percent of the value of the house when selling a house. Thus, the total transactions costs incurred when buying or selling a house are $\tau^b qh'$ and $\tau^s qh$. The presence of transactions costs reduces the transaction volume in the economy, and generates sizeable inaction regions with regard to the household decision to buy or sell. Therefore, only a part of the total housing stock is traded every period. The total housing supply and demand are thus determined endogenously, and are respectively upward and downward sloping functions of the house price. Similarly, the demand and supply of property in the rental market are endogenously determined, with rental supply determined by the individual demands for housing and shelter, $h' - s$.

Homeowners incur maintenance expenses, which offset physical depreciation of housing properties, so that housing does not deteriorate over time. Under this assumption, the total stock of housing, H, in the economy is fixed. The actual expense depends upon the value of housing, so that the total current maintenance costs facing an agent who has just chosen housing capital equal to h' is given by $M(h') = \delta^h qh'$. In addition to the maintenance cost, we follow Chambers, Garriga, and Schlagenhauf (2009a) and assume that landlords incur a fixed cost, ϕ, caused by the burden of maintaining and managing a rental property.

Homeownership confers access to collateralized borrowing at a constant markup over the risk-free deposit rate, r, so that $r^m = r + \kappa$. Borrowers must, however, satisfy a minimum equity requirement. In a steady state where the house price does not change across time, the minimum equity requirement is given by the constraint

$$m' \leq (1 - \theta)qh', \tag{3}$$

with $\theta > 0$. The equity requirement limits entry to the housing market, since households interested in buying a house with a market value qh' must put down at least a fraction θ of the value of the house. By the same token, households who wish to sell their house and move to a different size house or become renters must repay all the outstanding debt, since the option of mortgage default is not available. The accumulated housing equity above the down payment can, however, be used as collateral for home equity loans.[6]

2.4 The Government

This section describes our model of a progressive income tax system. The goal is to develop a parsimonious representation of the U.S. tax system which is progressive and captures the differential tax treatment of homeowners, landlords, and renters. Total income in the model is the sum of labor earnings, interest income, and net rental income,

$$y = w + rd + NRI. \tag{4}$$

Prior to defining NRI (which we do below), it is useful to discuss the current U.S. tax treatment of landlords and explain how the key features of the tax code are incorporated into our model. The U.S. tax system treats landlords as business entities. As a result, property owners are required to report all rental income received, but business expense can be used to offset it.[7] When property is rented, it is generally treated as two pieces of property—the part used as a home and the part used for rental. A tax payer must divide expenses between the personal and rental use.[8] The most notable expense items include but are not limited to mortgage interest paid, taxes, repairs and maintenance, or insurance. As a result, the net rental income, NRI, for a landlord is defined as:

$$NRI = \rho\,(h' - s) - [\tau^m r^m m(\frac{h' - s}{h'}) + \tau^h q(h' - s) + \delta^h q(h' - s) + \tau^{LL} q(h' - s)], \tag{5}$$

where $\rho\,(h' - s)$ represents the gross rental receipts; $\tau^m r^m m(\frac{h'-s}{h'})$ and $\tau^h q(h' - s)$ are the respective mortgage interest and property tax expenses for rental space, $h' - s$; and $\delta^h q(h' - s)$ represents the maintenance expenses. The last term, $\tau^{LL} q(h' - s)$, represents the tax deduction for depreciation of rental property available to landlords (i.e., depreciation allowance), where τ^{LL} represents the fraction of the total value of the rental property that is tax de-

[6] Similarly to Díaz and Luengo-Prado (2008), we abstract from income requirements when purchasing houses. See their paper for further discussion. Chambers, Garriga and Schlagenhauf (2006) and Campbell and Cocco (2003) offer a more complete analysis of mortgage choice. See Li and Yao (2007) for an alternative model with refinancing costs.

[7] According to the U.S. tax code, rental income must be reported by all tax payers who meet a minimum standard of involvement with their rental property. This minimum involvement is generally defined as the property being leased out for more than 14 days in a year.

[8] A unit is consider at home if used for personal purposes more than the greater of: 14 days, or 10 percent of the total days it was rented to others at fair market value.

ductible each year. The amount of the depreciation deduction is specified in the U.S. tax code, and we discuss the exact depreciation rate used in our model in Section 4. In addition, landlords who meet a minimum standard of involvement with their rental property may use rental losses to offset income earned from sources other than real estate.[9,10] As a result, if the net rental income is negative, so $\rho\,(h'-s) < [\tau^m r^m m(\frac{h'-s}{h'}) + \tau^h q(h'-s) + \delta^h q(h'-s) + \tau^{LL} q(h'-s)]$, then rental loss will reduce the households' tax liability by offsetting income from wages and interest, $w + rd$.

Taxable income is equal to total income minus allowable deductions,

$$\widetilde{y} = y - \psi(j),\ j \in \{R, O, L\}, \tag{6}$$

where the term $\psi(j)$ represents deductions from total income that differ for renters (R), owner-occupiers (O), and landlords (L). Tax deductions are not refundable, so $\widetilde{y} = 0$ if $y - \psi(j) < 0$.[11] Renters are permitted to deduct the following amount from their total income,

$$\psi(R) = \xi + e, \tag{7}$$

where ξ is the standard deduction, and e is the personal exemption. Homeowners and landlords can either claim the standard deduction, or can forego the standard deduction and choose to make itemized deductions from their total income. In our model, permissible itemized deductions are mortgage interest payments and property taxes. We assume that agents always choose the option that results in the maximum deduction from total income, so total deductions for a homeowner (a occupier or a landlord) are

$$\psi(O, L) = [e + max\{\xi, \tau^m r^m m(\frac{s}{h'}) + \tau^h q s\}], \tag{8}$$

where $\tau^m r^m m(\frac{s}{h'})$ and $\tau^h q s$ are the respective mortgage interest and property tax deductions for owner-occupied space.[12]

[9] A maximum of $\$25,000$ in rental property losses can be used to offset income from other sources, and this deduction is phased out between $\$100,000$ and $\$150,000$ of income. In our stylized model we abstract away from these features of the tax system. As it turns out, little is lost by ignoring these features, as the "offsetting" motive is not operative in the calibrated baseline model. In the calibrated baseline, no landlord uses her rental expenses to offset her non-rental income.

[10] Deductible expenses may exceed gross rental income, but a taxpayer must generally offset any passive rental loss from other passive income to deduct the loss.

[11] We are ignoring phasing out of deductions with income, as was the case in the U.S. prior to 2010.

[12] We also ignore phasing out of the offsetting of the non-rental income that can be done in the U.S. As it

We follow the U.S. tax code in modeling the progressivity of the tax function. The total taxes paid by an individual are

$$T(w, \widetilde{y}) = \tau^p w + \eta(\widetilde{y}), \tag{9}$$

where $\tau^p w$ is the payroll tax,[13] and where $\eta(\widetilde{y})$ is the progressive income tax function allows the marginal tax rate to vary over K levels of taxable income,

$$\begin{aligned} &\eta_1 \quad for \quad 0 \le \widetilde{y} < \pi_1 \\ &\eta_2 \quad for \quad \pi_1 \le \widetilde{y} < \pi_2 \\ &\vdots\vdots\vdots \\ &\eta_K \quad for \quad \pi_{K-1} \le \widetilde{y} < \pi_K. \end{aligned} \tag{10}$$

Implementing the progressive tax system requires creating deduction amounts (ξ, e) and cutoff income levels $\{\pi_k\}_{k=1}^K$ for use in the model that correspond to those in the U.S. tax system. We convert the dollar values found in the U.S. tax code into units appropriate for our model economy by normalizing using the average wage. Let $\bar{w}_d$ represent the average wage is the U.S. (we use the the median wage in 2009 from the Current Population Survey, CPS),[14] let ξ_d represent the standard deduction specified in the U.S. tax code, and let $\bar{w}$ represent the average wage in the model. The standard deduction in the model is

$$\xi = (\frac{\bar{w}}{\bar{w}_d})\xi_d. \tag{11}$$

The cutoff income levels for the tax code are converted in the same manner. In Section 5.2, we check the generated progressivity of the tax system in the model against available data. We do not require a balanced budget every period.

turns out, little is lost by ignoring this features of the tax code, as the "offsetting" motive is not operative in the calibrated baseline model. In the calibrated baseline, no landlord uses his rental expenses to offset her non-rental income.

[13]The average U.S. income tax rate was estimated at close to 10 percent in 2007 (CBO, 2010). At the same time, the average federal tax rate was reported at 20 percent. Adopting both the payroll tax and the progressive income tax allows us to capture both the average income tax rate and the average federal tax rate in the calibrated economy.

[14]The median wage for 2009 in the CPS is reported at $38,428.

2.5 The Dynamic Programming Problem

A household starts any given period t with a stock of residential capital, $h \geq 0$, deposits, $d \geq 0$, and collateral debt (mortgage and equity loans), $m \geq 0$. Households observe the idiosyncratic earnings shocks, w, and – given the current prices (q, ρ) – solve the following problem:

$$v(w,d,m,h) = \max_{c,s,h',d',m'} U(c,s) + \beta \sum_{w' \in W} \pi(w'|w) v(w',d',m',h') \tag{12}$$

subject to

$$\begin{aligned} & c + \rho\,(s - h') + d' - m' + q(h' - h) + I^s \tau^s qh + I^b \tau^b qh' \\ & \leq w \;+ (1+r)d - (1 + r^m)\,m - T(w, \widetilde{y}) - \tau^h qh' - M(h') - \phi I^{h'>s} \end{aligned} \tag{13}$$

$$m' I^{\{(m'>m)\cup(h'\neq h)\}} \leq (1-\theta)\,qh' \tag{14}$$

$$m' \geq 0 \tag{15}$$

$$d' \geq 0 \tag{16}$$

$$h' \geq s \;\; > 0 \; if \;\;\; h' > 0 \tag{17}$$

$$s > 0 \; if \;\;\; h' = 0, \tag{18}$$

by choosing non-durable consumption, c, shelter services consumption, s, as well as current levels of housing, h', deposits, d', and collateral debt, m'. The term $\rho\,(s - h')$ represents either a rental payment by renters (i.e., households with $h' = 0$), or the rental income received by landlords (i.e., households with $h' > s$). The term $q(h' - h)$ captures the difference between the value of the housing purchased at the start of the time period (h') and the stock of housing that the household entered the period with (h). Transactions costs enter into the budget constraint when housing is sold $(\tau^s qh)$ or bought $(\tau^b qh')$, with the binary indicators I^s and I^b indicating the events of selling and buying, respectively. Household labor income is represented by w, and it follows the process $\pi_w(w_t|w_{t-1})$ described in Section 2.1. Households earn interest income rd on their holdings of deposits in the previous period, and pay mortgage interest $r^m m$ on their outstanding collateral debt in the last period. The total federal and property tax payments are represented by $T(w, \widetilde{y})$ and $\tau^h qh'$, where

T is described in Section 2.3, and τ^h being the property tax rate. $M(h')$ represents the maintenance expenses for homeowners which is described in Section 2.3. Finally, equation 14 indicates that a household that either increases the size of its mortgage ($m' > m$) or moves to a different-sized home ($h' \neq h$) must satisfy the down payment requirement $m' \leq (1-\theta)qh'$.

3 Definition of a Stationary Equilibrium

In the benchmark economy, we restrict ourselves to stationary equilibria. The individual state variables are deposit holdings, d, mortgage balances, m, housing stock holdings, h, and the household wage, w; with $x = (w, d, m, h)$ denoting the individual state vector. Let $d \in \mathcal{D} = \mathbb{R}_+$, $m \in \mathcal{M} = \mathbb{R}_+$, $h \in \mathcal{H} = \{h_1, ..., h_{11}\}$, and $w \in \mathcal{W} = \{w_1, ..., w_7\}$, and let $\mathcal{S} = \mathcal{D} \times \mathcal{M} \times \mathcal{H} \times \mathcal{W}$ denote the individual state space. Next, let λ be a probability measure on $(\mathcal{S}, \mathcal{B}_s)$, where $\mathcal{B}_s$ is the Borel $\sigma-$algebra. For every Borel set $B \in \mathcal{B}_s$, let $\lambda(B)$ indicate the mass of agents whose individual state vectors lie in B. Finally, define a transition function $P : \mathcal{S} \times \mathcal{B}_s \rightarrow [0, 1]$ so that $P(x, B)$ defines the probability that a household with state x will have an individual state vector lying in B next period.

Definition (Stationary Equilibrium): A stationary equilibrium is a collection of value functions $v(x)$, a household policy $\{c(x), s(x), d'(x), m'(x), h'(x)\}$, probability measure, λ, and price vector (q, ρ) such that:

1. $c(x), s(x), d'(x), m'(x)$, and $h'(x)$ are optimal decision rules to the households' decision problem from Section 2.5, given prices q and ρ.

2. Markets clear:

   (a) Housing market clearing: $\int_{\mathcal{S}} h'(x) d\lambda = H$, where H is fixed

   (b) Rental market clearing: $\int_{\mathcal{S}} (h'(x) - s(x)) d\lambda = 0$,

   where $\mathcal{S} = \mathcal{D} \times \mathcal{M} \times \mathcal{H} \times \mathcal{W}$.

3. λ is a stationary probability measure: $\lambda(B) = \int_{\mathcal{S}} P(x, B) d\lambda$ for any Borel set $B \in \mathcal{B}_s$.

4 Calibration

The model is calibrated in two stages. In the first stage, values are assigned to parameters that can be determined from the data without the need to solve the model. In the second stage, the remaining parameters are estimated by the simulated method of moments (SMM). Table 1 and Table 2 summarizes the parameters determined in the first stage. These parameters were drawn from other studies or were calculated directly from the data. Table 3 contains the four remaining parameters that we estimate in the second stage based on moments constructed using the data from the American Housing Survey (AHS) and the Census Tables. These moments are listed in Table 4.

Table 1: Exogenous Parameters

Parameter	Value
Autocorrelation ρ_w	0.90
Standard Deviation σ_w	0.20
Risk Aversion σ	2.50
Down Payment Requirement θ	0.20
Selling Cost τ^s	0.07
Buying Cost τ^b	0.025
Risk-free Interest Rate r	0.04
Spread κ	0.015
Maintenance Cost Rate δ^h	0.015
Payroll Tax Rate τ^p	0.076
Property Tax Rate τ^h	0.01
Mortgage Deductibility Rate τ^m	1.00
Deductibility Rate for Depreciation of Rental Property τ^{LL}	0.023

4.1 Demography and Labor Income

To calibrate the stochastic aging economy, we assume that households live, on average, 50 periods (e.g., $L = 50$). In terms of the process for household productivity, many papers in the quantitative macroeconomics literature adopt simple AR(1) specification to capture the earnings dynamics for working-age households that is characterized by the serial correlation coefficient, ρ_w, and the standard deviation of the innovation term, σ_w.[15] Using data from

[15] Heathcote (2005) discusses alternatives to the AR(1) specification in a technical appendix which is available on the Review of Economic Studies web site.

the Panel Study of Income Dynamics (PSID), work by Card (1994), Hubbard, Skinner, and Zeldes (1995) and Heathcote, Storesletten, and Violante (2010) indicates a ρ_w in the range 0.88 to 0.96, and a σ_w in the range 0.12 to 0.25. For the purposes of this paper, we set ρ_w and σ_w to 0.90 and 0.20, respectively, and follow Tauchen (1986) to approximate an otherwise continuous process with a discrete number (7) of states.

4.2 Preferences

Following the literature on housing choice (see, for example, Díaz and Luengo-Prado (2008), Chatterjee and Eyigungor (2009), and Kiyotaki, Michaelides, and Nikolov (2011)), the preferences over the consumption of non-durable goods (c) and housing services (s) are modeled as non-separable of the form

$$U(c,s) = \frac{\left(c^{\alpha} s^{1-\alpha}\right)^{1-\sigma}}{1-\sigma}. \tag{19}$$

The risk aversion parameter, σ, is set to 2.5. The remaining parameters that characterize preferences are the weight on non-durable consumption of the Cobb-Douglas aggregator, α, and the discount factor, β. These two parameters are estimated in the second stage. Section 4.5 discusses our strategy for identifying these parameters.

Many recent studies assume that renters receive lower utility from a unit of housing services than homeowners. In this model, we assume that renters receive the same utility from housing services as homeowners, and allow other features of model – such as preferential taxation of housing – to endogenously generate a household preference for homeownership over renting. In Appendix A in Section 8, we show that ownership is preferred to renting primarily because of the imputed rents of homeowners are not taxed, while the rental income of landlords is (a result consistent with Diaz and Luengo-Prado, 2008).

4.3 Market Arrangements

Using data from the Consumer Expenditure Survey (CE), Gruber and Martin (2003) document that selling costs for housing are on average 7 percent, while buying costs are around 2.5 percent. We use the authors' estimates and set $\tau^b = 0.025$ and $\tau^s = 0.07$. In terms of the maintenance cost δ^h described in Section 2.3, we follow Bureau of Economic Analysis in using an estimate of 0.015.[16] The landlord penalty, ϕ, is estimated in the second stage (see Section 4.5).

To calibrate the interest rates on deposits r, we use the interest rate on the 30-year constant maturity Treasury deflated by year-to-year headline CPI inflation. Using the data from the Federal Reserve Statistical Release, the deflated Treasury rate averaged 3.8 percent for the period between 1977 and 2008.[17] We thus set the real interest rate to 4 percent so that $r = 0.04$. To calibrate the mortgage rate $r^m = r + \kappa$, we set the markup κ to represent the spread between the nominal interest rate on a 30-year fixed-rate conventional home mortgage and the interest rate on nominal 30-year constant maturity Treasury. The average spread between 1977 and 2008 is 1.5 percent, so κ is set to 0.015. In the baseline model, a minimum down payment of 20 percent is required to purchase a home.[18]

4.4 Taxes

Using data from the 2007 American Community Survey, Díaz and Luengo-Prado (2010) compute the median property tax rate for the median house value and report a housing property tax rate of 0.95 percent. Based on information from TAXSIM, they document that on average, 90 percent of mortgage interest payments are tax deductible. We thus set $\tau^h = 0.01$, and allow mortgages to be fully deductible so that $\tau^m = 1$. The U.S. tax code assumes that a rental structure depreciates over a 27.5 year horizon, which implies an annual depreciation rate of 3.63 percent. However, only structures are depreciable for tax purposes, and the value of a house in our model includes both the value of the structure and the land that the house is situated on. Davis and Heathcote (2007) find that on average, land accounts for 36 percent of the value of a house in the U.S. between 1975 and 2006. Based on their findings, we set the depreciation rate of rental property for tax purposes to $\tau^{LL} = (1 - .36) \times .0363 = .023$.

The payroll tax is set to $\tau^p = .076$ which is the average for all wage earners in 2007 (CBO, 2010).[19] Table 2 lists the deduction amounts, marginal tax rates, and cutoff income

[16] Harding, Rosenthal, and Sirmans (2007) estimate that the depreciation rate for housing units used as shelter is between 2.5 and 3 percent.

[17] See Federal Reserve Statistical Release, H15, Selected Interest Rates.

[18] Using the American Housing Survey 1993, Chambers, Garriga and Schlagenhauf document that the average down payment is approximately 20 percent.

[19] The 2011 payroll tax cut temporarily reduced the payroll tax rate to 5.6 percent.

Table 2: Progressive Tax System Parameters

Rate	Bracket Cutoffs
$\eta_1 = 10\%$	$0 - \$8,350$
$\eta_2 = 15\%$	$\$8,350 - \$33,950$
$\eta_3 = 25\%$	$\$33,950 - \$82,250$
$\eta_4 = 28\%$	$\$82,250 - \$171,550$
$\eta_5 = 33\%$	$\$171,550 - \$371,950$
$\eta_6 = 35\%$	$>\$371,950$
Personal exemption (e)	$\$3,650$
Standard deduction (ξ)	$\$5,700$

levels from the 2009 IRS tables for single filing.

As discussed in Section 2.4, we convert the dollar values found in the U.S. tax code into units appropriate for our model economy by normalizing using the median wage in 2009 from the CPS.

4.5 Estimation

After exogenously setting the previously discussed parameters to values based on the data, three structural parameters remain to be estimated: the Cobb-Douglas consumption share, α, the discount factor, β, and the fixed cost of being a landlord, ϕ. Let $\Phi = \{\alpha, \beta, \phi\}$ represent the vector of parameters to be estimated. We estimate these parameters using the simulated method of moments (SMM). Let m_k represent the $k-$th moment in the data, and let $m_k(\Phi)$ represent the corresponding simulated moment generated by the model. The SMM estimate of the parameter vector is chosen to minimize the squared difference between the simulated and empirical moments,

$$\widehat{\Phi} = \arg\min_{\Phi} \sum_{k=1}^{4} (m_k - m_k(\Phi))^2. \tag{20}$$

Minimizing this function is computationally expensive because it requires numerically solving the agents' optimization problem and finding the equilibrium house price and rent for each trial value of the parameter vector.

The four moments targeted during estimation are the homeownership rate, the landlord rate, the imputed rent-to-wage ratio ($\frac{\rho s}{w}$), and the fraction of homeowners who hold collateral debt. The remainder of this section details the data sources for the targeted moments and discusses how the parameters (Φ) impact the simulated moments. The share parameter α affects the allocation of income between non-durable consumption and shelter by agents in the model. This motivates our use of the imputed rent-to-wage ratio as a targeted moment. Using data from 1980, 1990, and 2000 Decennial Census of Housing,Davis and Ortalo-Magné (2010) estimate the share of expenditures on housing services by renters to be roughly 0.25, and find that the share has been constant across time and MSA regions. The discount factor, β, directly impacts the willingness of agents to borrow, so we attempt to match the fraction of owner-occupiers with collateral debt. According to data from the 1994-1998 American Housing Survey (AHS), approximately 65 percent of homeowners report collateral debt balances.[20]

The final two targeted moments are the homeownership rate and landlord rate. According to Census Bureau data, the homeownership rate was approximately 65 percent in the United States between 1970 and 1996 before reaching 69 percent in 2006 and subsequently falling below 66 percent during the second quarter of 2011. To capture the long-term equilibrium level, we thus set the calibration target for homeownership at 0.65. Chambers, Garriga, and Schlagenhauf (2009a) use the American Housing Survey data to compute the fraction of homeowners who claim to receive rental income. The authors find that approximately 10 percent of the sampled homeowners receive rental income. Targeting the homeownership and landlord moments implies that we are also implicitly targeting the fraction of households who are renters (0.34) and owner-occupiers (0.56) because the landlord, renter, and owner-occupier categories are mutually exclusive and collectively exhaustive. The homeownership and landlord moments provide information about the magnitude of the landlord fixed cost, ϕ. As ϕ increases from zero, holding the house price and rent constant, landlords who rent out small amounts of shelter are priced out of the market. As a result, in equilibrium, an increase in the landlord fixed cost affects the composition of the landlord pool in the baseline economy.

Estimated Parameters (Φ): Table 3 shows the estimated parameters, and Table 4 demonstrates that the model matches the empirical moments used in estimation well.

[20] The discount pattern β governs household borrowing behavior in our model. Since deceased agents in our model are replaced by newborn descendants who do not, however, inherit the asset positions of the dead, we calibrate β to ensure that households do not borrow excessively and to generate a realistic borrowing behavior of households in our model economy.

Table 3: Estimated Parameters

Parameter	Value
Discount Factor β	0.987
Consumption Share α	0.695
Fixed Cost For Landlords ϕ	0.062

Table 4: Calibration Targets

Moment	Data	Model
Home-ownership rate	0.65	0.65
Landlord rate	0.10	0.10
Expenditure share on housing	0.25	0.25
Fraction of homeowners with collateral debt	0.65	0.65

5 Baseline Model

5.1 Moments not Targeted in the Estimation

As an external text of our model, we report several other key statistics generated by the model that were not targeted in the estimation and compares them to statistics that are either drawn from other studies, or are computed from the 1998 and 2007 waves of Survey of Consumer Finances (SCF). Appendix C in Section 10 shows how we compute these moments in the SCF data.

In terms of cross-sectional moments, the model generates loan to value ratio for homeowners of 0.29. The corresponding values were 0.35 in both SCF 1998 and SCF 2007. The baseline ratio of house value to total income generated by the model for homeowners is 4.85; again roughly in line with the data (4.43 in SCF 1998 and 5.36 in SCF 2007). In terms of the loan to income ratio for homeowners, the model predicts a ratio of 1.58, while corresponding SCF statistics are 1.28 for 1998 and 1.41 for 2007. Finally, net worth to income for homeowners was 3.53 in the model, compared to 3.53 in SCF 1998 and 4.28 in SCF 2007.

In terms of credit constraints, the model predicts that a fraction of liquidity constrained agents is consistent with the available empirical evidence. Following Hall (2011) and Iacoviello and Pavan (2011), we take a model agent to be liquidity-constrained if the holdings of net liquid assets are less than two months (16.67 percent on an annual basis) of income. Using this definition, 28 percent of households are liquidity constrained.[21] Japelli (1990) estimates the share of liquidity constrained individuals to be 20 percent. Iacoviello and Pavan (2011) argue that 20 percent is likely to be a lower bound.

Turning to the aggregate moments, the model predicts the average income tax rate in the economy to be 0.106 vs 0.093 in the 2007 data (CBO, 2010). In the same vein, the average federal tax rate (i.e., income and payroll tax) in the model is 0.19 and matches well the CBO's estimate of 0.20 for 2007 (CBO, 2010). Finally, in terms of the relative price of shelter, the model predicts the baseline house price-rent ratio of 14.3. The U.S. Department of Housing and Urban Development and the U.S. Census Bureau report a price-rent ratio of 10 in the 2001 Residential Finance Survey (chapter 4, Table 4-2). Garner and Verbrugge (2009), using Consumer Expenditure Survey (CE) data drawn from five cities over the years 1982-2002, report that the house price to rent ratio ranges from 8 to 15.5 with a mean of approximately 12. The cities included in this analysis are Chicago, Houston, Los Angeles, New York, and Philadelphia. Finally, Davis, Lehnert and Martin (2007) use Decennial Censuses of Housing surveys between 1960 and 1995 to construct a quarterly time series of the rent-price ratio for the aggregate stock of owner-occupied housing in the United States. They find that the price-rent ratio ranged between 18.8 and 20 between 1960 and 1995.

Overall, the ability of our model to approximately replicate a number of key moments that were not targeted during the calibration is encouraging.

5.2 Progressivity of Taxation in the Baseline Model

In this section, we compare the generated progressivity of the tax system in the baseline model against the available data estimates. Gouveia and Strauss (1994) estimate the individual average tax rate as a function of total income using United States tax return data for tax years 1979 to 1989. The function is specified as

$$atr = b - b(sy^p + 1)^{1/p},$$

[21] Iacoviello and Pavan (2011) generate 45 percent of constrained households in their economy, but this result is partly driven by the differences in assumed patience. In their model, 67 percent of impatient agents and only 2 percent of patient agents are liquidity constrained.

where y represents the total income (in thousands of dollars), with parameters $b = 0.258$, $s = 0.031$ and $p = 0.768$ estimated for the year 1989 (the last year for which estimates are available). To test the progressivity of taxation in our baseline model, we use the total income, y, in equation 4 and simulate the average tax rate of each household in the baseline economy using the Gouveia-Strauss tax function.[22] In the second step, we compare these Gouveia-Strauss estimates against the effective tax rates generated in the model. We follow Gouveia and Strauss (1994) in excluding payroll taxes from the computation of the effective tax rates in the model (to ensure that the simulated effective tax rates are directly comparable).[23] Figure 1 compares the average tax rate by income quintiles generated by the baseline model against Gouveia-Strauss estimates. As can be seen in the figure, the model matches the Gouveia and Strauss estimates well, although it tends to understate the effective tax rate for the lowest quintiles.

For completeness, although not directly comparable, Panel A in Figure 2 captures the average tax rate when payroll taxes are included in the calculation of the effective tax rate, and matches the increasing trend of average federal tax rates for 2007 reported by the Congressional Budget Office (CBO). The overall trend is, however, less progressive than the CBO estimates. This is because in the U.S., a large share of lower-income U.S. households pay negative income tax (due to various deductions that are not explicitly modeled here), which drives the effective tax rates for the lower income quintiles down relative to the model. In fact, the lowest two quintiles of the U.S. income distribution paid on average negative individual income tax every year since 2002, according to the CBO data.[24] Panel B shows the share of total income and taxes paid by each income quintile. Again, as in the data, higher income groups earn a disproportionate share of pretax income and pay a disproportionate share of federal taxes. In the model, the top income quintile holds 37 percent of the total income in the economy but contributes 44 percent of all taxes paid; compared to the data where the top income quantile earned 55.9 percent of pre-tax income and paid roughly 0.70 percent of federal taxes in 2007 (CBO, 2010).

[22] As described in Section 2.4, we use the CPS 2009 median wage to translate the model units into the dollar amounts that can directly fed into the Gouveia-Strauss tax function.

[23] The definition of tax in the Gouveia-Strauss paper corresponds to a strict notion of an income tax and excludes sums that pertain to social security obligatons.

[24] The lowest quintile has paid negative individual income tax every year since 1987.

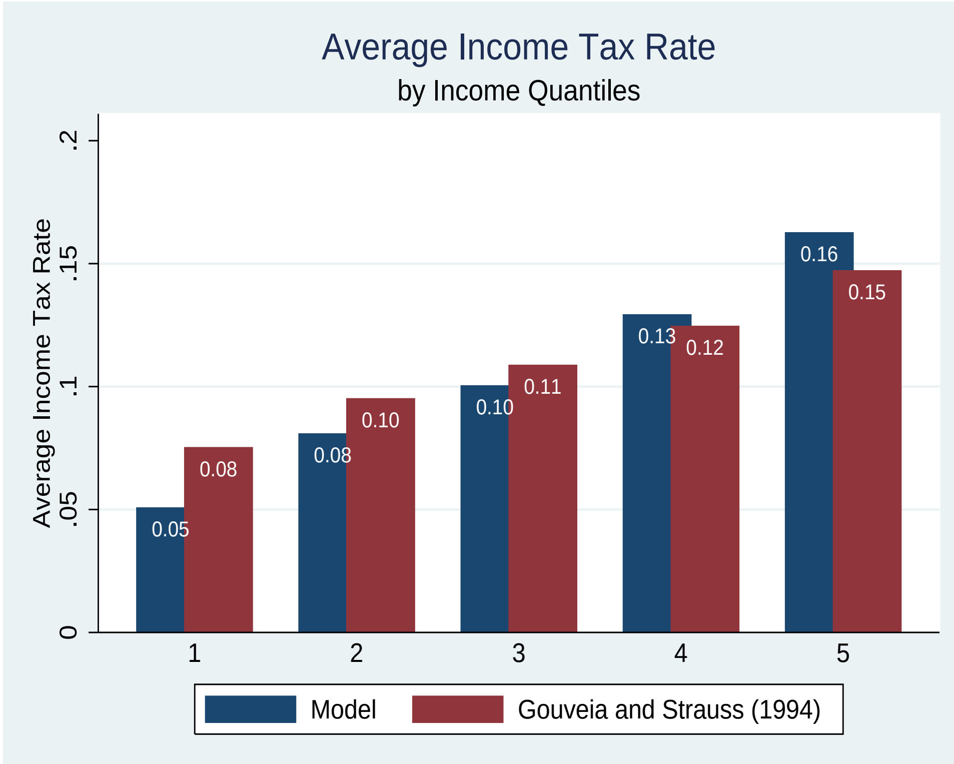

Figure 1: Comparison of the income tax system's progressivity in the baseline model against Gouveia-Strauss (1994) estimates

Notes: We follow Gouveia and Strauss (1994) in excluding payroll taxes from the computation of the average tax rates generated by the model.

5.3 Renters, Occupiers and Landlords: How are they being taxed?

In this section, we ask what are the tax characteristics of landlords, occupiers and renters. In the model, renters are low-income, low-savings households with average federal tax rates (i.e., income plus payroll tax) between 10 and 20 percent. Occupiers are middle-income households who are taxed at substantially higher tax rates than renters; with average federal tax rates between 20 and 30 percent.[25] Landlords are typically households with high wage realizations and high life-time income purchase rental properties as an investment or to reduce their taxable income. An average landlord has a 2 times higher life-time income than an average occupier (and 12 times higher than an average income of a renter), and offsets more than two thirds of her rental income with rental expenses; the rental expense to rental income

[25] A very small fraction of the wealthiest occupiers (0.69 percent) occupy the largest structure in the economy. These households have 1.6 times higher current labor income and 1.4 times higher life-time income than an average landlord owning the same size structure. Similarly, the average mortage of these households, on average, 50 percent smaller than the collateralized debt of the landlord with the same property.

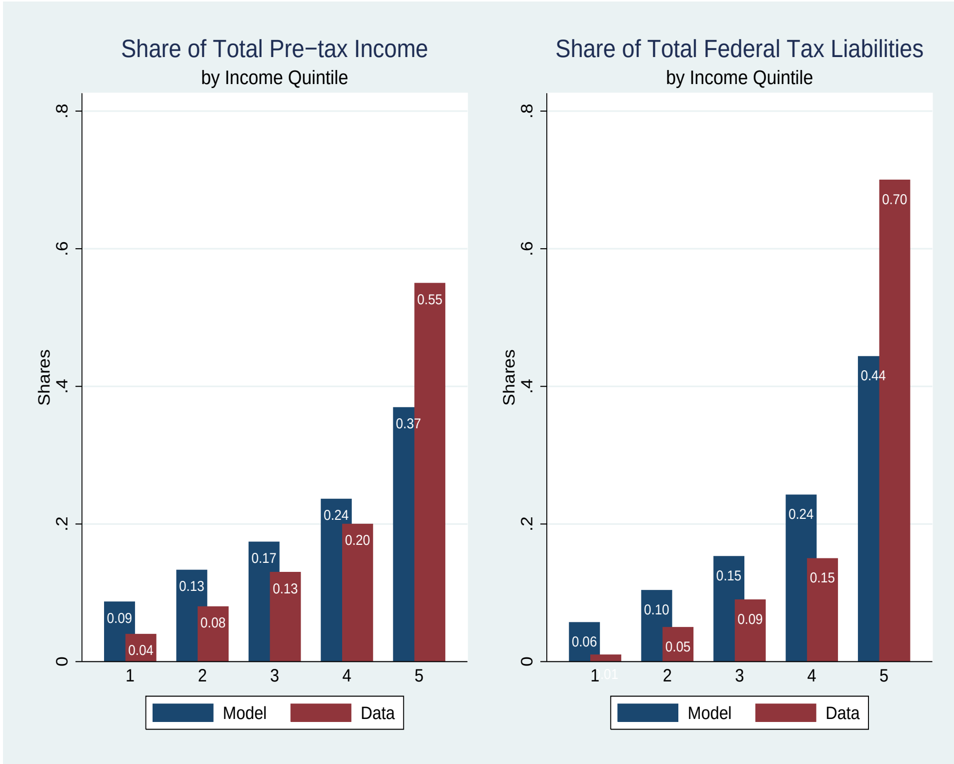

Figure 2: Indirect comparison of the share of total income and taxes paid by income quitile

ratio is 69.5 percent.[26] In the baseline economy, landlords own almost exclusively the largest property. A negligible number of landlords (2.4 percent) own, however, medium sized houses that they partially rent out to avoid incurring high transaction costs related to downsizing when an adverse labor income shock hits.[27]

5.4 Who Gets Deductions?

Although mortgage interest and property tax deductions are available to all homeowners, high income families benefit far more form these tax incentives that low-income families.[28] Taxpayers with incomes of $100,000 or more accounted for 11 percent of all tax returns but claimed more then 54 percent of the $59 billion in mortgage interest deductions taken in

[26] Although offsetting non-rental income with rental losses is permitted in the model, there are no landlords with a negative net rental income who would use thier rental expenses (such as mortgage interest payments, property taxes or maintenance expenses) to offset their non-rental income.

[27] Ideally, we would want to compare these predictions against data, but a data set that contains both an information on a homeowership status of a household and tax records is not currently readily available.

[28] First, deductions become more valuable with rising income; a $1,000 deduction is worth $350 into a taxpayer in the top tax bracket but just $100 to a taxpayer in the lowest bracket. Second, the use of homeowner deductions declines with income because lower income homeowners are less likely to itemize their tax deductions.

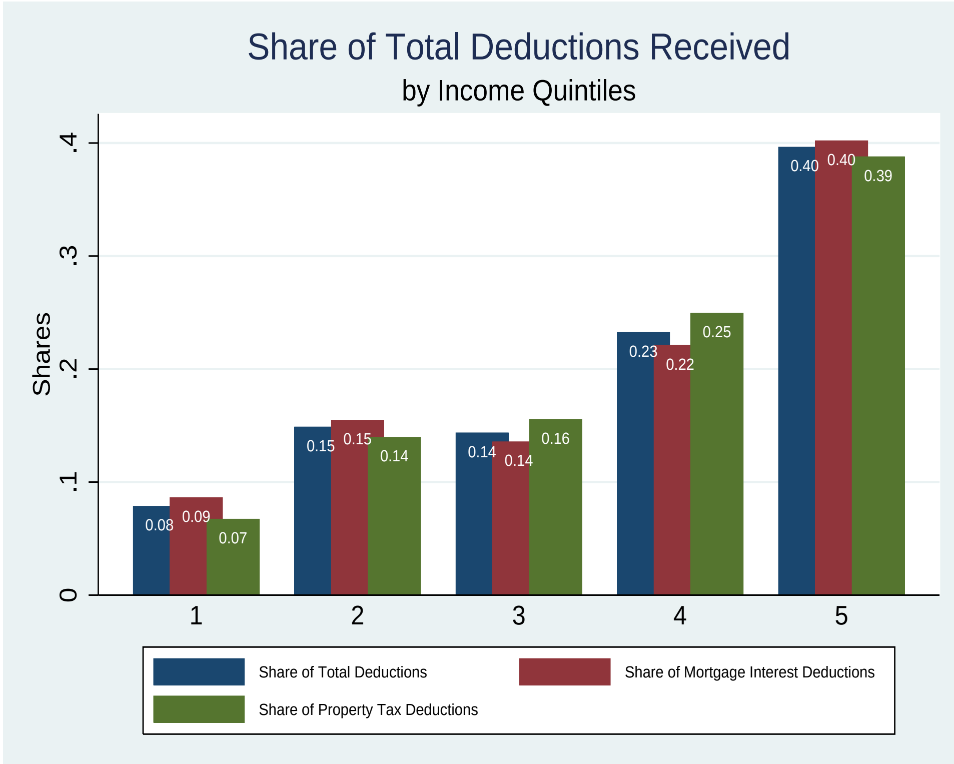

Figure 3: Share of the housing tax deductions by income quintiles

the fiscal year of 2004 (JTC, 2010).[29] The distribution of property tax deductions closely parallels that of mortgage tax deductions. For example, homeowners with incomes over $110,999 accounted for half of the value of property tax deductions in 2004, but those earning less than $30,000 receive less than 3 percent (Schwartz, 2006). The uneven distribution of homeowner tax expenditures in illustrated in Figure 3, which show the extent to which mortgage interest and property tax deductions benefit different income groups. The figure shows the distribution of tax deductions received by households across income quintiles. As in the data, the distribution of mortgage tax deductions is vastly uneven, with the top income quintile receiving roughly 37 percent of both mortgage interest and property tax deductions.

Table 5: The Effect of Eliminating the Mortgage Interest and Property Tax Deductions

	Prices			Ownership Choices			Tax Revenue			Overall	
	q	ρ	$\frac{q}{\rho}$	own	rent	land.	inc.	prop.	total	tax inc.	ATR
Baseline	2.99	0.21	14.13	0.65	0.35	0.10	3,719	983	4,702	22,394	0.11
Mortgage Interest	-8.5%	-2.5%	-6.2%	0.72	0.28	0.08	4.2%	-8.5%	2.7%	3.0%	7.3%
Property Tax	-2.5%	-0.2%	-2.2%	0.67	0.33	0.09	1.9%	-2.5%	1.1%	1.4%	3.5%
$\tau^{LL} = 0.0125$	-7.9%	-3.5%	-4.4%	0.69	0.31	0.09	1.2%	-7.9%	1.4%	0.1%	1.2%

Notes: All entries other than the line for the baseline are percentage changes relative to the baseline economy. Ownership choices for the baseline are fractions of the population. Abbreviations: land. = landlords, inc. = income, prop. = property, tax inc. = total taxable income, ATR = average income tax rate (excludes 7.6% payroll tax).

6 Experiments

6.1 The Mortgage Interest Deduction

We start our analysis by exploring the role of the mortgage interest tax deduction – the hallmark of the U.S. housing policy – on house prices, rents, and homeownership. Mortgage tax deductions constitute the largest homeownership subsidy under the current tax code: the total tax expenditure toward owner-occupied housing in 2011 was estimated at 93.8 billion (Joint Committee on Taxation, Estimates of Federal Tax Expenditures for Fiscal Years 2010-2014, December 15, 2010).

The mortgage interest deduction enters the baseline model in two distinct ways. First, owner-occupiers can reduce their taxable income by claiming this deduction. Second, landlords can use mortgage interest deductions (along with other operating expenses such as maintenance cost or property taxes) to partly offset rental income.[30] Consistent with the tax treatment of business entities, mortgage interest deductions available to landlords are not considered tax expenditures under the U.S. tax code.[31] In the U.S., tax expenditures are defined with reference to a normal income tax structure (also known as "normal income

[29] On the other hand, taxpayers earnings up to $30,000 account for 45% of all tax returns but less than 2% of total mortgage tax deductions.

[30] Under the U.S. tax code, the operating expense could, in principle, exceed the rental income value, in which two options exists. First, a maximum of $25,000 in rental property losses can be used to offset non-rental income, and this deduction is phased out between $100,000 and $150,000 of income. Second, remaining passive losses can be carried over to future years. In our economy, optimizing homeowners will never become landlords if non-positive rental income were to be generated.

[31] In the U.S., tax expenditures include any reduction in income liabilities that result from special tax provisions or regulations that provide tax benefit to particular tax papers (JTC 2010).

tax law"). Under the "normal tax law," individuals are allowed to deduct the interest on indebtedness incurred in connection with a trade or business or an investment, but cannot deduct interest related to personal expenses (JCT 2010). Thus, the deduction for mortgage interest on a principal or second residence is classified as tax expenditure, while the mortgage interest deduction available to landlords is not.[32]

Table 5 shows the effect of repealing mortgage interest deductions for owner-occupied space. As the table illustrates, when the housing supply is relatively inelastic, the value of the mortgage interest deduction is capitalized into house prices. When mortgage interest deductions are eliminated, house prices fall by 8.5 percent because, ceteris paribus, as the cost of ownership has risen. At the same time, homeownership rises from 65 percent to 72.4 percent, as the reduced house price level lowers the minimum down payment required to purchase a house ($\theta q h'$), prompting renters to enter the housing market. Rent falls by 2.5 percent due to the reduced demand for rental space, and the fraction of landlords in the economy declines from 10 to 8 percent. The generated effects are consistent with the empirical findings by Hilber and Turner (2010), who exploit the variation in the mortgage deduction subsidy across states and time to examine the impact of the mortgage tax deduction on homeownership. In particular, the authors tests whether capitalization of the mortgage tax deduction into house prices offsets the positive effect on homeownership. The authors find that the mortgage tax deductions are on average associated with higher house prices and reduced homeownership. The effect is particularly strong in regions where housing supply is relatively inelastic. In less tightly regulated market, availability of mortgage interest deductions mostly boosts homeownership attainment of higher income households. The predictions of our model, and in Hilber and Turner (2010), that preferential treatment of homeownership reduces homeownership stands in a marked contrast to the commonly accepted notion that mortgage interest deductions are always homeownership-promoting.

From a tax revenue perspective, repealing mortgage interest deductions for owner-occupied space leads to a 4.2 percent increase in the income tax revenue as taxable income rises, but a decrease in property tax revenue caused by the house price decline. The property tax revenue ($\tau^h q H$) declines by proportionally with house prices (i.e., by 8.5 percent), as the aggregate supply of housing (H) is fixed. At this point, it is useful to discuss the channels

[32] Repealing mortgage tax deduction (or other operating expenses) available to landlords creates asymmetries in the tax treatment of landlords and other businesses for which these deductions are available.

behind the observed increase in taxable income. When mortgage interest deductions are eliminated, the value of total deductions (ψ) falls and taxable income rises. However, the corresponding decline in the house price level also reduces value of property tax deductions; thus further decreasing the value of total deductions and re-enforcing the increase in taxable income. In general, the decline in property tax revenue corresponding to the increase in income tax revenue highlights the asymmetric effect of eliminating mortgage interest deductions on the ability to balance budgets by federal versus state and local governments. The importance of property taxes as source of revenue for state and local governments is discussed next.

6.2 Property Tax Deductions

Estimated at 22.8 billion for 2011 (JTC 2010), the deduction for property taxes on real estate represents the second largest tax expenditure related to housing. At the same time, property taxes represent an important source of revenue for state and local government. Property taxes accounted for about 22 percent of state and local government revenue in 2005, according to the National Association of Home Builders.

In line with the size of total dollar expenditure on property taxes relative to mortgage tax deductions, the effect of eliminating property tax deductions for owner-occupied space has less pronounced effect on the housing market equilibrium than repealing mortgage tax deductions. However, the total effect is notable nonetheless, as it leads to a 2.5 percent drop in the house price, a trivial (0.02 percent) decrease in rent, and a 1.7 percent increase in homeownership (Table 5). In terms of the mechanism, the same forces are operative as in the mortgage interest deduction experiment. Eliminating property taxes for owner-occupied space increases the cost of housing, thus reducing demand. In equilibrium, house prices fall and the homeownership rate rises, as down payments ($\theta q h'$) are reduced. Finally, rents fall due to the reduced demand for rental space. Similarly, income tax revenue increases by 1.9 percent due to increased levels of taxable income, while property tax revenue ($\tau^h q H$) declines by 2.5 percent due to lowered house prices. However, the mechanism behind the changes in taxable income works in reverse from the mortgage interest tax experiment. When property tax deductions are eliminated, the value of total deductions (ψ) falls and taxable income rises. The marginal decrease in house price level, however, also means that household need less collateralized debt to finance housing consumption. The decline in household mortgage debt thus further increases taxable income as the value of mortgage deductions falls.[33]

6.3 Depreciation Deductions Available to Landlords

The federal tax code provides subsidies to rental properties vis-à-vis other investment to the extent that it permits the owner of a rental building to take depreciation deductions that exceed the real rate of economic depreciation. In theory, depreciation deductions enable owners of rental housing and other types of commercial real estate to invest in its physical upkeep property by allowing owners to reduce their taxable income to free up funds to invest in capital improvements needed as a result of the wear and tear that time (Alex F. Schwartz, Housing Policy in the United States: An Introduction, New York: Routledge, 2006). The standard method for calculating depreciation is "straight-line" depreciation, calculated by dividing the depreciable basis (total development minus land and other non-depreciable expenses) by the number of years of the depreciation period: 27.5 years.

Historically, the depreciation deduction is viewed as the most prominent rental market subsidy, although its importance was vastly curbed in the second half of the 1980s. Prior to the 1986 Tax Reform, the depreciation deduction for rental property became notorious as a vehicle that allowed high earnings households to generate "paper losses" that could be used to offset household income for tax purposes, including non-rental income such as earnings or income from investments (Schwartz, 2006). The Tax Reform Act of 1986 (TRA86) reduced tax rates in the highest income bracket, adopted a conservative depreciation scheme, and prevented households from offsetting very large amounts of non-rental income with "paper" losses from rental investments. After the 1986 Tax Reform, the importance of the depreciation deduction fell dramatically: the total depreciation deduction in the first year of acquisition of a rental investment property with a taxable basis of $200,000 fell from $18,421 before 1986 to only $7,273 in 1986 (Schwartz, 2006). Hansmann (1991) argues that the reduced tax subsidies to rental properties (primarily through the depreciation subsidy) contributed to the decline in the prominence of rental properties and an increase in the prevalence of condominiums and cooperative housing since the 1986 tax reform.[34]

[33] The changes in household borrowing resulting from changes in the tax treatment suggest that accounting for equilibrium effects of interest rates may be important. In the future, we intend to endogenize interest rate in addition of the equilibrium house prices and rents.

[34] This finding is consistent with the contraction of the rental market: multifamily housing starts decreased

Table 6 shows the effect of doubling the length of the depreciation period for 27.5 to 55 years (through decreasing τ^{LL} to 0.0125 from its baseline value of 0.023). As table 5 illustrates, even after the 1986 tax reform had reduced its prominence as a rental market tax subsidy, the depreciation deduction continues to have a sizable impact on the housing market equilibrium. When the deduction is reduced, the cost of rental investment rises sharply, leading to a reduced demand for large rental investment properties. Absent shifts in housing demand, reducing depreciation deductions would lead to higher rents. However, the lowered housing demand by landlords leads to a 7.9 percent decline in house prices and a 3.5 percent decline in rents, as renters – prompted by lowered minimum down payments – enter the housing market. As a result, the homeownership rate rises by 4 percent from 0.65 to 0.69. At the same time, the fraction of landlords in the economy falls from 10 to 9 percent because investing in rental property is less attractive. Moreover, since the tax treatment of owner-occupied space is unchanged, existing homeowners consume more shelter as house prices fall. In this experiment, landlords essentially sell parts of their rental properties to entering renters and existing homeowners, although this does not happen literally because we are comparing different steady states in this experiment.

Turning to tax revenue effects, increasing the number of years of the depreciation period from 27.5 to 55 years leads to a 1.2 increase in income tax revenue and a 7.9 percent decline in property tax revenue. Two channels are jointly operative in generating the increase in income tax revenue. First, when house prices fall, household de-leverage in the long-run, as less mortgage debt is needed to finance housing purchases. This increases the taxable income of homeowners by decreasing the total value of mortgage interest deductions. Second, lower house prices decrease the value of property deductions. Finally, the decrease in rental income due to reduced rents is more than compensated for by a reduction in business expense that are used by landlords to offset rental income. As a result, the total value of net rental income rises, even as the supply of rental property and the number of landlords in the economy fall.

every year from 1985 to 1993. As a share of total housing starts, the multifamily sector fell from 33% in 1985 to 15% in 1991 and 11% in 1993. It is not until the second half of the 1990s that multifamily starts began to recover, but they are yet to climb back to the volumes of the 1980s and late 1970s (Schwartz, 2006).

7 Conclusion

This paper estimated the impact of reducing housing tax preferences on equilibrium house prices and rents using a dynamic stochastic life cycle model of housing choice. To analyze the effects of housing tax expenditures on the tenure choice and house prices, we built a model with a realistic tax system in which the owner-occupied housing services are tax-exempt and mortgage interest payments, property taxes, and landlord's business costs are tax deductible. We simulated the effect of various tax reform proposals on house prices, rents, homeownership and tax revenue. Considered experiments included the effect of eliminating mortgage interest deductions and property tax deductions for owner-occupied space, as well as a reduction in depreciation allowances available to landlords. Through simulations, we found that when housing supply is relatively inelastic, repealing deductions leads to a decline in house prices, but higher homeownership. This is because deductions are capitalized into house prices, but higher price level leads to crowding out of aspiring homeowners from the housing market. Our results challenge the widely adopted view that mortgage interest deductions promote homeownership. We also examined the effect of tax reform on the ability of federal and local governments to balance budgets. In the preliminary set of experiments that are not revenue-neutral, we found that repealing deductions leads to an increase in income tax revenue through increases in taxable income, but property tax revenue falls as house prices decline. In the future, we plan on extending our analysis with experiments that are economically neutral, and we plan on endogenizing the interest rate.

8 Appendix A: Frictionless Analytical Results

Consider a problem of a homeowner who consumes all housing services yielded by the owned property (e.g., $s = h'$) but also chooses how much to invest into a rental property, h'_r. For simplicity, we assume that the borrower does not face any borrowing constraints and that there are no buying and selling costs, or income uncertainty. The homeowner thus chooses (c, h', h'_r, m', d') to optimally solve:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c, h')$$

subject to initial conditions and

$$
\begin{aligned}
& c + d' - m' + qh' + qh'_r \\
& \leq w \ + (1+r)d - (1+r^m)\, m + \rho h'_r + qh + qh_r - T(w, \widetilde{y}) - \tau^h qh' - \tau^h qh'_r - \delta^h qh' - \delta^h qh'_r - \phi I^{h'>s},
\end{aligned}
$$

where

$$
\widetilde{y} = w + rd + \rho h'_r - \left[\tau^m r^m m + \tau^h qh' + \tau^h qh'_r + \delta^h qh'_r + \tau^{LL} qh'_r\right].
$$

The corresponding first order conditions are:

$$
\begin{aligned}
c &: u_c(c, h') - \lambda = 0, \\
h' &: u_h(c, h') + \lambda(-\tau^y \frac{\partial \widetilde{y}}{\partial h'} - \tau^h q - \delta^h q - q) + \lambda' q' = 0 \text{ where } \tau^y \frac{\partial \widetilde{y}}{\partial h'} = -\tau^y \tau^h q, \\
h'_r &: \lambda(\rho - \tau^y \frac{\partial \widetilde{y}}{\partial h'_r} - \tau^h q - \delta^h q - q) + \lambda' q' = 0 \text{ where } \tau^y \frac{\partial \widetilde{y}}{\partial h'_r} = \tau^y(\rho - \tau^h q - \delta^h q - \tau^{LL} q), \\
d' &: -\lambda + \lambda'(-\tau^y \frac{\partial \widetilde{y'}}{\partial d'} + (1+r)) = 0 \text{ where } \tau^y \frac{\partial \widetilde{y'}}{\partial d'} = \tau^y r, \\
m' &: \lambda + \lambda'(-\tau^y \frac{\partial \widetilde{y'}}{\partial m'} - (1+r^m)) = 0 \text{ where } \tau^y \frac{\partial \widetilde{y'}}{\partial m'} = -\tau^y r^m.
\end{aligned}
$$

Combining the first order conditions with respect to c and h', we obtain the expression representing the user cost of a homeowner,

$$
\frac{u_h(c_t, h')}{u_c(c_t, h')} = q(1 + (1-\tau^y)\tau^h + \delta^h) - \frac{\lambda'}{\lambda} q'. \tag{21}
$$

Similarly, the first order condition with respect to h'_r gives the asset pricing equation for a landlord in this frictionless economy:

$$
\rho = \frac{q(1 + (1-\tau^y)\tau^h + (1-\tau^y)\delta^h - \tau^y \tau^{LL}) - \frac{\lambda'}{\lambda} q'}{(1-\tau^y)}. \tag{22}
$$

Equations 21 and 22 can be used to compare the cost of housing of a renter to that of a homeowner. Landlords can access deductions not available to homeowners, such as physical depreciation of the rental property and maintenance costs. However, rental property depreciates at a higher rate, and rental income (unlike user-occupied space) is taxable. Letting

$C := 1 + (1-\tau^y)\tau^h - \frac{\lambda'}{\lambda}$, then in steady-state, equations 21 and 22 become

$$\frac{u_h(.)}{u_c(.)} = q(C + \delta^h)$$
$$(1-\tau^y)\rho = q(C + (1-\tau^y)\delta^h - \tau^y\tau^{LL})$$

Clearly, the taxability of rental income is of central importance; at our calibrated parameter values, $\frac{u_h(.)}{u_c(.)} < \rho$ primarily due to the tax treatment of rental income – a result consistent with Díaz and Luengo-Prado (2008). Moreover, Díaz and Luengo-Prado (2008) show that when there is a spread between the return on deposits and the mortgage rate (as in here), then households do not simultaneously hold deposits and debt; see their Proposition 2. As a result, using the first order conditions with d' and m', the user cost and the landlord asset pricing equations above can be further simplified by substituting $\frac{\lambda'}{\lambda} = \frac{1}{1+(1-\tau^y)r}$ if the homeowner holds deposits, or $\frac{\lambda'}{\lambda} = \frac{1}{1+(1-\tau^y)r^m}$ if the homeowner holds a mortgage loan.

9 Appendix B: Solving the Model

9.1 Finding Equilibrium in the Housing and Rental Markets

Equilibrium in the housing and rental markets is formally defined by the conditions presented in Section 3. In practice, the market clearing rent (ρ^*) and house price (q^*) are found by finding the (q^*, ρ^*) pair that simultaneously clear both the housing and shelter markets in a simulated economy. The market clearing conditions for a simulated cross section of N agents are

$$\sum_{i=1}^{N} h_i'(q^*, \rho^*|x) = H \tag{23}$$
$$\sum_{i=1}^{N} s_i'(q^*, \rho^*|x) = H. \tag{24}$$

The optimal housing and shelter demands for each agent are functions of the market clearing steady state prices and the agents other state variables (x). Solving for the equilibrium of the housing market is a time consuming process because it involves repeatedly re-solving the optimization problem at potential equilibrium prices and simulating data to check for market clearing until the equilibrium prices are found. The algorithm outlined in the following section exploits theoretical properties of the model such as downward sloping demand when searching for market clearing prices. Taking advantage of these properties dramatically decreases the amount of time required to find the equilibrium relative to a more naive search algorithm.

9.2 The Algorithm

Let q_k represent the kth guess of the market clearing house price, let ρ_k represent a guess of the equilibrium rent, and let $\rho_k(q_k)$ represent the rent that clears the market for housing conditional on house price q_k. The algorithm that searches for equilibrium is based on the following excess demand functions

$$ED_k^h(q_k, \rho_k) = \sum_{i=1}^{N} h_i'(q_k, \rho_k|x) - H \tag{25}$$

$$ED_k^s(q_k, \rho_k) = \sum_{i=1}^{N} s_i'(q_k, \rho_k|x) - H. \tag{26}$$

The equilibrium prices q^* and ρ^* simultaneously clear the markets for housing and shelter, so

$$ED_k^h(q^*, \rho^*) = 0 \tag{27}$$

$$ED_k^s(q^*, \rho^*) = 0. \tag{28}$$

The following algorithm is used to find the market clearing house price and rent.

1. Make an initial guess of the market clearing house price q_k.

2. Search for the rent $\rho_k(q_k)$ which clears the market for owned housing conditional on the current guess of the equilibrium house price, q_k. The problem is to find the value of $\rho_k(q_k)$ such that $ED_k^h(q_k, \rho_k(q_k)) = 0$. This step of the algorithm requires re-solving the agents' optimization problem at each trial value of $\rho_k(q_k)$, simulating data using the policy functions, and checking for market clearing in the simulated data. One useful property of the excess demand function $ED_k^h(q_k, \rho_k(q_k))$ is that conditional on q_k, it

is a strictly decreasing function of ρ_k. Based on this property, $\rho_k(q_k)$ can be found efficiently using bisection.

3. Given that the *housing* market clears at prices $(q_k, \rho_k(q_k))$, check if this pair of prices also clears the market for *shelter* by evaluating $ED^s_k(q_k, \rho_k(q_k))$.

   (a) If $ED^s_k(q_k, \rho_k(q_k)) < 0$ and $k = 1$, the initial guess q_1 is too high, so set $q_{k+1} = q_k - \varepsilon$ and go to step (2). This initial house price guess q_1 is too high if $ED^s_k(q_k, \rho_k(q_k)) < 0$ because $ED^s_k(q_k, \rho_k(q_k))$ is decreasing in q_k.

   (b) If $ED^s_k(q_k, \rho_k(q_k)) > 0$ set $k = k + 1$ and $q_{k+1} = q_k + \varepsilon$ and go to step (2).

   (c) If $ED^s_k(q_k, \rho_k(q_k)) = 0$, the equilibrium prices are $q^* = q_k$, $\rho^* = \rho_k(q_k)$, so stop.

10 Appendix C: SCF Data (not for publication)

The Survey of Consumer Finances (SCF) 1998 and 2007 is used to construct the cross-sectional moments cited in the study. The SCF is a triennial survey of the balance sheet, pension, income, and other demographic characteristics of U.S. families. The total housing wealth is constructed as the total sum of all residential real estate owned by a household, and is taken to represent the housing wealth qh' in the model. Secured debt (i.e., debt secured by primary or other residence) is used as a model analog of the collateralized debt, m'. The model analogue of the total net worth (i.e., $d' + qh' - m'$) is constructed as the sum of household's deposits in the transaction accounts and the housing wealth (as defined above), net of the secured debt. The total household income reported in the SCF is taken to represent the total household income defined in the model as $y = w + rd' + NRI - \tau^{LL}q(h' - s)$. Data and the SAS code are available at request, but both can be also found at the SCF website.

References

Campbell, J. and J. Cocco (2003). Household Risk Management and Optimal Mortgage Choice. *Quarterly Journal of Economics 118*(4), 1449–1494.

Card, D. (1994). Intertemporal labor supply: An assessment. In C. Sims (Ed.), *Advances in Econometrics*. Cambridge University Press.

Castaneda, A., J. Díaz-Gimenez, and J. Ríos-Rull (2003). Accounting for the US earnings and wealth inequality. *Journal of Political Economy 111*(4), 818–857.

Chambers, M., C. Garriga, and D. Schlagenhauf (2009a). Accounting for changes in the homeownership rate. *International Economic Review 50*(3), 677–726.

Chambers, M., C. Garriga, and D. Schlagenhauf (2009b). The loan structure and housing tenure decisions in an equilibrium model of mortgage choice. *Review of Economic Dynamics 12*(3), 444–468.

Chambers, M., C. Garriga, and D. E. Schlagenhauf (2009c). Housing policy and the progressivity of income taxation. *Journal of Monetary Economics 56*(8), 1116 – 1134.

Chatterjee, S. and B. Eyigungor (2009). Foreclosures and House Price Dynamics: A Quantitative Analysis of the Mortgage Crisis and the Foreclosure Prevention Policy. *Federal Reserve Bank of Philadelphia Working Paper*, 09–22.

Davis, M. and J. Heathcote (2007). The price and quantity of residential land in the United States. *Journal of Monetary Economics 54*(8), 2595–2620.

Davis, M. and F. Ortalo-Magné (2010). Household expenditures, wages, rents. *Review of Economic Dynamics*.

Díaz, A. and M. Luengo-Prado (2008). On the user cost and homeownership. *Review of Economic Dynamics 11*(3), 584–613.

Díaz, A. and M. Luengo-Prado (2010). The Wealth Distribution with Durable Goods. *International Economic Review 51*(1), 143–170.

Gervais, M. (2002). Housing taxation and capital accumulation. *Journal of Monetary Economics 49*(7), 1461–1489.

Gervais, M. and M. Pandey (2008, March). Who cares about mortgage interest deductibility? *Canadian Public Policy 34*(1), 1–24.

Gruber, J. and R. Martin (2003). Precautionary savings and the wealth distribution with illiquid durables. *Federal Reserve Board International Finance Discussion Paper No. 773*.

Harding, J., S. Rosenthal, and C. Sirmans (2007). Depreciation of housing capital, maintenance, and house price inflation: Estimates from a repeat sales model. *Journal of Urban Economics 61*(2), 193–217.

Heathcote, J. (2005). Fiscal policy with heterogeneous agents and incomplete markets. *Review of Economic Studies 72*(1), 161–188.

Heathcote, J., K. Storesletten, and G. Violante (2010). The macroeconomic implications of rising wage inequality in the united states. *Journal of political economy 118*(4), 681–722.

Hilber, C. A. L. and T. M. Turner (2010, September). The mortgage interest deduction and its impact on homeownership decisions. SERC Discussion Papers 0055, Spatial Economics Research Centre, LSE.

Hubbard, R., J. Skinner, and S. Zeldes (1995). Precautionary saving and social insurance. *The Journal of Political Economy 103*(2), 360–399.

Kiyotaki, N., A. Michaelides, and K. Nikolov (2011). Winners and losers in housing markets.

Li, W. and R. Yao (2007). The life-cycle effects of house price changes. *Journal of Money, Credit and Banking 39*(6), 1375–1409.

Nakajima, M. (2010). Optimal capital income taxation with housing. Technical report.

Poterba, J. (1984). Tax subsidies to owner-occupied housing: an asset-market approach. *The Quarterly Journal of Economics 99*(4), 729–752.

Poterba, J. M. (1992, May). Taxation and housing: Old questions, new answers. *American Economic Review 82*(2), 237–42.

Poterba, J. M. and T. Sinai (2011). Revenue costs and incentive effects of the mortgage interest deduction for owner-occupied housing. In *Economic Analysis of Tax Expenditures*, NBER Chapters. National Bureau of Economic Research, Inc.

Rosen, H. S. (1979, February). Housing decisions and the u.s. income tax : An econometric analysis. *Journal of Public Economics 11*(1), 1–23.

Tauchen, G. (1986). Finite state Markov-chain approximations to univariate and vector autoregressions. *Economics letters 20*(2), 177–181.