

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

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July 2017

Abstract

This paper studies the impact of the mortgage interest tax deduction on equilibrium house prices, rents, homeownership, and welfare. We build a dynamic model of the housing market that features a realistic progressive tax system in which owner-occupied housing services are tax-exempt, and mortgage interest payments are tax deductible. We simulate the effect of tax reform on the housing market. Eliminating the mortgage interest deduction causes house prices to decline, increases homeownership, decreases mortgage debt, and improves welfare. Our findings challenge the widely held view that repealing the preferential tax treatment of mortgages would depress homeownership.

*We would like to thank Timothy Erickson, Andrew Haughwout, Jonathan Heathcote, Mark Huggett, Fatih Karahan, Weicheng Lian, Ellen McGratten, William Peterman, Victor Rios-Rull, Erick Sager, Don Schlagenhauf, and participants of the 2013 HUML Conference at the Federal Reserve Bank of St. Louis, the Applied Microeconomics Seminar Series at the Federal Reserve Board, Georgetown University, the Federal Reserve Bank of Atlanta, the 2014 ASSA Meetings, the Federal Reserve Bank of New York, Wesleyan University, the University of Western Ontario, and the Center for Retirement Research at Boston College for helpful comments and suggestions. Significant portions of this research were completed while Sullivan visited the University of Western Ontario. He thanks this institution for its hospitality. The analysis and conclusions contained in this paper are those of the authors and do not necessarily reflect the views of the Board of Governors of the Federal Reserve System, its members, or its staff.

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1 Introduction

Estimated to provide a \$90 billion subsidy to homeowners just in the year 2013, the mortgage interest deduction is one of the largest tax expenditures in the United States (JCT, 2012). This lost revenue amounts to approximately 7 percent of total personal income tax payments. In the ongoing debate over budget deficits and fiscal reform, eliminating the mortgage interest deduction has been a frequently discussed policy change. Proponents of reform point out that the mortgage interest deduction reduces government revenue, is a regressive tax policy, and subsidizes mortgage debt. Opponents argue that repealing the preferential tax treatment of mortgages would depress homeownership and reduce social welfare. To be sure, since housing is the single-most important asset for the vast majority of households, federal income tax policy has first-order effects on housing consumption, house values, homeownership, and welfare. However, the degree to which the repeal of the mortgage interest deduction would affect these objects is ultimately a quantitative question about the magnitude of the resulting equilibrium change in the after-tax cost of homeownership.

This paper studies the repeal of the mortgage interest deduction using an equilibrium model of the housing market that features endogenous house prices and rents. We quantify the general equilibrium effects of tax reform both in the steady state and along the dynamic transition path that occurs when the mortgage interest deduction is suddenly and unexpectedly eliminated from the tax code. We build a stochastic life cycle Aiyagari-Bewley-Huggett economy 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. Mortgages are available, but home-buyers must satisfy a minimum down payment requirement, and moving is subject to lumpy transaction costs. A progressive tax system mimics the U.S. tax code, and includes the itemized tax deductions available to homeowners and landlords that are important determinants of housing demand and rental supply. A housing construction sector allows for a supply response to tax reform. Having calibrated the model by matching a number of relevant moments of the U.S. economy, we use it to assess the implications of repealing the mortgage interest deduction for house prices, rents, homeownership and welfare.

The model demonstrates that repealing the regressive mortgage interest deduction decreases housing consumption by the wealthy, increases aggregate homeownership, improves overall welfare, and leads to a decline in aggregate mortgage debt. The mechanisms behind these results are intuitive. When both house prices and rents are allowed to adjust, the repeal of the mortgage interest deduction decreases house prices because, *ceteris paribus*, the after-tax cost of occupying a square foot of housing has risen. Reduced house prices allow low wealth, credit-constrained households to become homeowners because the minimum down payment required to purchase a house falls. At the same time, the elimination of the tax favored status of mortgages, acting in concert with the fall in equilibrium house prices, causes unconstrained households to reduce their mortgage debt. Because rents remain roughly constant as house prices decline, homeownership becomes cheaper relative to renting, which further re-enforces the positive effect of eliminating the mortgage interest deduction on homeownership. Importantly, the expected lifetime welfare of a newborn household rises because the tax reform shifts housing consumption from high income households (the main beneficiaries of the tax subsidy in its current form) to lower income families for whom the additional shelter consumption is relatively more valuable. Our findings stand in sharp contrast to the widely held view that repealing the preferential tax treatment of mortgages would depress homeownership and reduce welfare.¹

Having established the positive effect of the repeal of the mortgage interest deduction on steady state homeownership and welfare, we turn to a related, and hotly debated policy question: What are the effects of suddenly, and unexpectedly, eliminating the mortgage interest deduction? This experiment begins with the sudden repeal of the mortgage interest deduction, which surprises households owning houses and holding mortgages that were optimal under the *baseline* tax regime. After the initial shock to the system, house prices and rents follow the rational-expectations transitional path to the new steady state. We find that, on average, households benefit from the repeal, with 58 percent of households alive at the time of the reform experiencing an improvement in their future realized welfare. However, welfare effects vary widely across the population, with winners and losers from the reform differing systematically in their housing tenure, mortgage debt, and labor income at the time of the reform. In particular, while renters and middle-income households generally

¹ Hilber and Turner (2014) provide empirical evidence that the mortgage interest deduction fails to promote homeownership. This paper includes a thorough survey of the related empirical literature.

benefit from the repeal, high-income households with large mortgages and high marginal tax rates frequently incur sizable welfare losses over their lifetime.

Commensurate with its important role in the housing market, the impact of housing tax policies has been widely studied (for seminal papers, see Laidler (1969), Aaron (1970), Rosen (1985), and Poterba (1984, 1992)). More recently, other authors have used theoretical dynamic models in the quantitative macroeconomic tradition to study these issues. By and large, these studies have not allowed both house prices and rents to be endogenous (see Gervais (2002), Díaz and Luengo-Prado (2008), Nakajima (2010), and Chambers, Garriga and Schlagenhauf (2009a,c,b)). 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, homeownership and household welfare. When the house price level is fixed (as in the influential work by Gervais 2002), repealing mortgage interest deductions increases the cost of ownership but does not reduce down payment requirements. When the user cost rises while house prices are unchanged, the homeownership rate falls. Our model shows that when house prices are allowed to adjust in response to the elimination of mortgage interest deductions, the homeownership rate actually increases.

In subsequent work to this paper, Floetotto et al. (2016) use this study’s framework to endogenize both house prices and rents, and explore the effects of eliminating mortgage interest deductions in an economy with a flat income tax. However, abstracting away from progressive taxation eliminates the key distortion generated by the interaction between progressive taxation and the mortgage interest tax subsidy; namely, the fact that the value of the deduction increases with household income, and the associated marginal tax rates.²

Recognizing the importance of the interaction between housing tax subsidies with the progressive tax code, Chambers, Garriga and Schlagenhauf (2009b) 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,c,b), who document that the majority of rental properties in the

²Moreover, the authors study the simultaneous elimination of homeowner and landlord mortgage interest deductions. Section 5.1 discusses the distinction between the tax expenditure on owner-occupier mortgage interest, and the deduction for landlord mortgage interest that is in keeping with the goal of taxing net, rather than gross, business income.

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.³ Similarly to Chambers, Garriga and Schlagenhaut (2009b), 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 Schlagenhaut (2009b), 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, leading to increases in household income and wealth along with 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 bolsters these effects in our paper: both the house price and the price-to-rent ratio fall, thereby reducing down payments and increasing affordability.

Other recent papers have used alternative frameworks to study these issues. Of note, Rapoport (2016) analyzes the incidence and efficiency loss from mortgage subsidies in a theoretical model with endogenous housing supply. Similar to this paper, he finds that the mortgage interest deduction hurts first-time home buyers by increasing house prices. While he is unable to quantify the effect on homeownership, the author finds that the mortgage interest deduction generates efficiency losses by increasing household leverage and distorting allocation of credit.

2 The Model Economy

Heterogeneous households derive utility from nondurable consumption and from shelter services which are obtained either via renting or 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

³ Sommer, Sullivan and Verbrugge (2013) develop a related model with endogenous house prices and rents, and examine the effect of interest rates and down payment requirements on the housing market. This paper does not incorporate progressive taxation or study the effect of the mortgage interest rate deduction on the housing market.

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 operating expenses are tax-deductible. 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 population grows proportionally at a constant rate n , and 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 a 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.⁴ The probability of transiting from a state w_j via aging is equal to $\chi_j = 1/(p_j L)$, 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 $\pi(w_i|w_j)$, is therefore equal to the probability of transition from j to i via aging, plus the probability of transition from

⁴Unlike in a deterministic life cycle model, where income has a deterministic age component, in a stochastic life cycle model, the age component is random.

j to i via a productivity shock, conditional on not aging, so that

$$\Pi = \begin{bmatrix} 0 & \chi_1 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \chi_{J-1} \\ \chi_J & 0 & 0 & 0 \end{bmatrix} + \begin{bmatrix} (1 - \chi_1) & 0 & 0 & 0 \\ 0 & \ddots & 0 & 0 \\ 0 & 0 & (1 - \chi_{J-1}) & 0 \\ 0 & 0 & 0 & (1 - \chi_J) \end{bmatrix} P. \quad (1)$$

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, upon death, estates are taxed at a 100 percent rate by the government and immediately resold. All proceeds of these sales are not re-distributed, but are instead used to finance government expenditures that do not affect individuals.

2.2 Preferences

The 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 $U(c, s)$, where c stands for nondurable consumption and s represents consumption of shelter services. Shelter services can be obtained either via the rental market at price ρ per unit or through 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 .⁵

⁵The model assumes that households do not simultaneously hold deposits (d) and collateral debt (m).

Houses are big items that are available in $K = 18$ discrete sizes, $h \in \{0, h(1), \dots, h(K)\}$. Households may choose not to own a house ($h' = 0$), in which case they obtain shelter through the rental market. Households can rent a small unit of shelter, \underline{s} , which is smaller than the minimum house size available for purchase, $\underline{s} < h(1)$.⁶ Renters are also free to rent any of the larger amounts of shelter on the housing grid, so for renters, $s \in \{\underline{s}, h(1), \dots, h(K)\}$.

Houses are costly to buy and sell. Households pay a non-convex transaction cost 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 transaction costs incurred when buying or selling a house are the sum of $\tau^b q h'$ and $\tau^s q h$. The presence of transaction costs generates sizable inaction regions with respect to the household decision to buy or sell, so only a fraction of the total housing stock is traded in any given time period.

Homeowners incur maintenance expenses which offset physical depreciation of housing properties, so housing does not deteriorate over time. The actual expense depends upon the value of housing, so the total current maintenance costs facing an agent who has just chosen housing capital equal to h' is given by $M(h') = \delta^h q h'$. In addition to maintenance expenses, we follow Chambers, Garriga and Schlagenhaut (2009a) in assuming that landlords also incur a fixed cost, ϕ , from 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 over time, the minimum equity requirement is given by the constraint

$$m' \leq (1 - \theta) q h', \quad (2)$$

with $\theta > 0$. The equity requirement limits entry to the housing market, since households interested in buying a house with a market value $q h'$ 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.⁷ Along the transitional

⁶An online appendix shows the distribution of households across shelter sizes for both renters and homeowners.

⁷Similarly to Díaz and Luengo-Prado (2008), we abstract from income requirements when purchasing

path where house prices fluctuate, the operational constraint becomes

$$m' I^{\{(m' > m) \cup (h' \neq h)\}} \leq (1 - \theta)qh'. \quad (3)$$

This modified version of the constraint in Equation 2 implies that homeowners need not decrease their collateral debt balance during house price declines, as long as they do not sell their house. On the other hand, when house prices rise, households can access the additional housing equity through a pre-approved home equity loan.⁸

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. Let y represent the sum of labor earnings (w), interest income (rd), and rental income net of tax deductible expenses (TRI),

$$y = w + rd + TRI. \quad (4)$$

Prior to defining taxable rental income, TRI , 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 expenses can be used to offset it. When part of a property is owner-occupied, and part of it is rented out, for tax purposes it is generally treated as two pieces of property—the part used as a home and the part used for rental. A taxpayer must divide expenses between the personal and rental use. The most notable expenses include, but are not limited to, mortgage interest, repairs, and maintenance. As a result, taxable rental income, TRI , for a landlord is defined as:

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

houses. See their paper for further discussion. Chambers et al. (2009c) 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.

⁸In a steady-state environment where prices are constant, Equation 3 reduces to Equation 2.

where $\rho(h' - s)$ represents the gross rental receipts; $r^m m(\frac{h'-s}{h'})$ 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 deductible 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 3. In addition, landlords may use rental losses to offset income earned from sources other than real estate.⁹

Taxable income is equal to total income minus allowable deductions,

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

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 $\tilde{y} = 0$ if $y - \psi(j) < 0$.¹⁰ Renters are permitted to deduct the following amount from their total income,

$$\psi(R) = \xi + e, \quad (7)$$

where ξ is the standard deduction and e is the personal exemption. Homeowners and landlords can either claim the standard deduction, or can forgo 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 (an occupier or a landlord) are

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

where $\tau^m r^m m(\frac{s}{h'})$ and $\tau^h qs$ are the respective mortgage interest and property tax deductions for owner-occupied space.¹¹

⁹A 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 rental expenses to offset non-rental income.

¹⁰We abstract away from phasing out of deductions with income, as was the case in the U.S. prior to 2010.

¹¹The term τ^m allows for the possibility that mortgage interest on owner-occupied space is not fully tax

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

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

where $\tau^p w$ is the payroll tax,¹² and where $\eta(\tilde{y})$ is the progressive income tax function that allows the marginal tax rate to vary over K levels of taxable income,

$$\begin{aligned} \eta_1 & \text{ for } 0 \leq \tilde{y} < b_1 \\ \eta_2 & \text{ for } b_1 \leq \tilde{y} < b_2 \\ & \vdots \\ \eta_K & \text{ for } b_{K-1} \leq \tilde{y} < b_K. \end{aligned} \quad (10)$$

Implementing the progressive tax system requires creating deduction amounts (ξ, e) and cutoff income levels $\{b_k\}_{k=1}^K$ 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 in the U.S., 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

$$\xi = \left(\frac{\bar{w}}{\bar{w}_d}\right)\xi_d. \quad (11)$$

The cutoff income levels for the tax code are converted in the same manner. In Section 4.2, we check the progressivity of the tax system in the model against available data. Finally, as in Díaz and Luengo-Prado (2008), all proceeds from taxation are used to finance government expenditures that do not affect individuals.¹³

deductible.

¹²The 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.

¹³The treatment of proceeds from taxation is consistent with the treatment of proceeds from sales of estates of deceased agents, previously discussed in Section 2.1.

2.5 The Dynamic Programming Problem

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

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

subject to

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

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

$$m' \geq 0 \quad (15)$$

$$d' \geq 0 \quad (16)$$

$$h' \geq s \text{ if } h' > 0 \quad (17)$$

by choosing non-durable consumption, $c > 0$, shelter services consumption, $s > 0$, 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). Transaction 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 $\pi(w_t|w_{t-1})$ 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 $T(w, \tilde{y})$ and $\tau^h qh'$, where the function $T(\cdot)$ is described in Section 2.3, and τ^h is the property tax rate. $M(h')$ represents the maintenance expenses for homeowners which are described in

Section 2.3, and ϕ represents the fixed cost incurred by landlords. Finally, Equation 14 represents the collateral requirement.

2.6 Housing Supply

Having described the household problem, we close the model by introducing a housing supply sector. A large literature, such as Davis and Heathcote (2005), focuses on important macroeconomic questions regarding the cyclical behavior of residential construction and GDP by building multi-sector, representative agent growth models. Given our focus on tax policy and household welfare, we instead build a model that focuses on household heterogeneity and equilibrium prices in the housing and rental markets, and adopt a tractable model of housing supply that can be straightforwardly estimated. Our approach is based on two key assumptions. First, it is consistent with the intuitively appealing idea that long-run growth in the U.S. housing stock is to a large degree driven by population growth. Second, it assumes that the dynamics of the aggregate housing stock, H , are also governed by the responsiveness of residential investment, I , to changes in house prices. Hence, insofar as house prices respond to changes in the tax treatment of housing, so will housing investment (and therefore the aggregate stock of housing).

Recall that in our model, population grows at constant rate n , so the total population evolves over time as follows, $N' = (1 + n)N$. Residential investment, I , is proportional to the current stock of housing, H ,

$$I = f(q, \varepsilon)H, \tag{18}$$

where $f(q, \varepsilon)$ is the constant elasticity supply function for residential investment, H is the current stock of housing, and the parameter ε represents the elasticity of residential investment with respect to the house price (q). A linear technology translates residential investment into housing, so the law of motion for the aggregate stock of housing is a standard capital accumulation equation,

$$H' = H + I. \tag{19}$$

Equation 19 does not include depreciation of housing capital, because homeowners in the model are required to pay maintenance expenses that offset physical depreciation.¹⁴ The

¹⁴That is, a homeowner is not permitted to allow his house to shrink in size by failing to maintain it. Endogenizing expenditures to offset depreciation is not feasible in the current model for two primary

supply function satisfies the restriction $f(q^*, \varepsilon) = n$, so in steady state equilibrium, the per-capita housing stock remains constant.¹⁵

Under this specification, and highly relevant for our tax experiments at hand, the aggregate housing stock, H , responds not only to increases in population but also to the counterfactual tax reforms studied in this paper. Specifically, tax reforms that shift the demand for housing interact with the supply function, $f(q, \varepsilon)$, to determine the equilibrium price and quantity of housing. Section 3.5 discusses estimation of the supply elasticity, ε .

2.7 Stationary Equilibrium

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 $d \in \mathcal{D} = \mathbb{R}_+$, $m \in \mathcal{M} = \mathbb{R}_+$, $h \in \mathcal{H} = \{0, h_1, \dots, h_K\}$, and $w \in \mathcal{W} = \{w_1, \dots, w_7\}$, 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 σ -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. 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: $\int_{\mathcal{S}} h'(x) d\lambda = H$,

- (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 $B \in \mathcal{B}_s$.

reasons. First, this would add another endogenous choice variable to an already high dimensional household choice problem. Second, housing (and shelter) choices are on a discrete grid.

¹⁵The baseline economy is a stationary equilibrium where market prices are constant at their steady state values (q^*, ρ^*) , which implies that the per-capita housing stock must remain constant. If the per-capita housing stock was not stationary, the house price would not converge to a stationary value.

Table 1: Exogenous Parameters

Parameter	Value
Autocorrelation of Labor Income Shocks (ρ_w)	0.90
Standard Deviation of Labor Income Shocks (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
Mortgage Interest Rate 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
Population Growth Rate (n)	0.01

3 Calibration

The model is calibrated in three stages. In the first stage, a number of parameter values are drawn from other studies or obtained directly from data sources. Tables 1 and 2 summarize the first stage parameters determined in this manner. In the second stage, the housing supply function is parameterized by estimating the supply elasticity parameter. In the third stage, the three remaining structural parameters are calibrated by matching simulated moments from the model to empirical moments. Table 3 shows the three remaining parameters determined in this manner, and also shows the supply elasticity estimate from the second stage. The empirical moments targeted during calibration in the third stage are listed in Table 4.

3.1 Demography and Labor Income

To calibrate the stochastic aging economy, we assume that population grows at a rate $n = 0.01$, and that households live, on average, 50 periods (i.e., $L = 50$).¹⁶ In terms of the process for household productivity, many papers in the quantitative macroeconomics literature adopt simple AR(1) specifications characterized by the serial correlation coefficient, ρ_w , and the

¹⁶The U.S. population grew at an average annual rate of one percent between 1990 and 2016 (U.S. Census).

standard deviation of the innovation term, σ_w . Using data from the Panel Study of Income Dynamics (PSID), work by Card (1994), Hubbard, Skinner and Zeldes (1995) and Heathcote, Storesletten and Violante (2010) indicates a value for ρ_w in the range of 0.88 to 0.96, and a value for σ_w in the range of 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 approximate an otherwise continuous process with a discrete number (7) of states.

3.2 Preferences

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

$$U(c, s) = \frac{(c^\alpha s^{1-\alpha})^{1-\sigma}}{1-\sigma}. \quad (20)$$

The risk aversion parameter, σ , is set to 2.5.¹⁷ 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 calibrated by matching simulated moments from the model to empirical moments. Section 3.6 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 instead 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.¹⁸

¹⁷An online appendix examines the sensitivity of our results to assuming a lower level of risk aversion ($\sigma = 1.5$). The quantitative responses of the model to the elimination of the mortgage interest deduction are quite similar under the lower level of risk aversion.

¹⁸Appendix A in Sommer, Sullivan and Verbrugge (2013) demonstrates that ownership is preferred to renting primarily because the imputed rents of homeowners are not taxed, while the rental income of landlords is taxed (a result consistent with Diaz and Luengo-Prado, 2008).

3.3 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 approximately 2.5 percent. We use the authors' estimates and set $\tau^b = 0.025$ and $\tau^s = 0.07$. Following Díaz and Luengo-Prado (2008), the housing depreciation/maintenance cost δ^h described in Section 2.3 is set to 0.015, which falls within the range of estimates in Harding, Rosenthal and Sirmans (2007). The landlord fixed cost, ϕ , is calibrated (see Section 3.6).

To calibrate the interest rate 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 2008.¹⁹ We thus set the real interest rate to 4 percent so that $r = 0.04$.²⁰ 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.²¹

3.4 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 mortgage interest 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.

¹⁹See Federal Reserve Statistical Release, H15, Selected Interest Rates.

²⁰An online appendix examines the response of the model to tax reform under a lower interest rate of $r = 0.02$. The effects are qualitatively similar, although they are quantitatively more attenuated.

²¹In this class of model where there is no loan approval process, θ serves as a proxy for the overall tightness of mortgage underwriting conditions.

Table 2: Progressive Tax System Parameters

Tax Parameter	
(A) Marginal Rate	Bracket Cutoff
$\eta_1 = 10\%$	\$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
(B) Deduction	Amount
Personal exemption (e)	\$3,650
Standard deduction (ξ)	\$5,700

Based on their findings, we set the depreciation rate of rental property for tax purposes to $\tau^{LL} = (1 - 0.36) \times 0.0363 = 0.023$. The payroll tax rate is based on the 2009 level so that $\tau^P = 0.076$. Table 2 lists the deduction amounts, marginal tax rates, and cutoff income 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 using the median wage in 2009 from the Current Population Survey (CPS).²²

3.5 Estimating the Housing Supply Elasticity

The supply response to housing tax reform in the model is governed by the housing supply function, $f(q, \varepsilon)$, which was introduced in Section 2.6. The price elasticity of supply, ε , is an unknown parameter that must be estimated. We estimate a constant elasticity supply function,

$$\log(I) = XB + \varepsilon \log(P), \quad (21)$$

where I is the quantity of residential investment supplied, X is a vector of variables that affect supply, and P is the house price. Residential investment is measured using the BEA quantity index for real private residential investment. The house price data series is the real residential property price index for the U.S. from the Bank for International Settlements.²³

²²The median wage for 2009 in the CPS is \$38,428.

²³In real terms, this price series is very highly correlated with the CoreLogic house price index. The estimated supply elasticity is effectively identical using this alternative data series.

All variables are measured at a yearly frequency, and span the years 1975 to 2014.

It is inappropriate to estimate the supply elasticity using a simple OLS regression of residential investment on house prices, because prices are endogenous. The natural solution is to instrument for price using a variable that shifts demand. Following this standard practice, we estimate Equation 21 by instrumental variables, using real disposable personal income from the BEA national accounts data as an instrument.²⁴ The R^2 of the first stage regression is 0.695, so personal income is a strong predictor of house prices. The IV estimate of the elasticity parameter, shown in Table 3, is $\widehat{\varepsilon}_{IV} = 0.9025$, with a standard error of 0.171.²⁵

The estimated price elasticity of supply falls within the relatively wide range of values found in the literature. The empirical framework that is perhaps most similar to ours is Poterba (1984). The author estimates an investment supply function for single family housing structures, and reports elasticity estimates ranging between 0.50 and 2.0. Topel and Rosen (1988) estimate a supply function for housing starts, and report a short run elasticity of 1.0, and a long run elasticity of 3.0. Although there is a large empirical literature on housing supply elasticities, many of the existing estimates do not correspond particularly well with the aggregate elasticity in our model. For example, many existing studies focus on small geographic regions, or are based on dependent variables, such as housing starts, that are difficult to translate into units appropriate for our model that features multiple house sizes. As a result of these considerations, we use our own estimate of the elasticity of residential investment with respect to house prices, instead of relying on an external estimate.

3.6 Calibrated Parameters

After setting the previously discussed parameters, three structural parameters remain to complete the model: 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 calibrated. The parameter vector is chosen to minimize the squared difference between

²⁴We estimated alternative specifications of the supply function that included additional explanatory variables (X), such as measures of construction costs. These variables had little explanatory power, and did not change the estimated elasticity appreciably. As a result, we set the elasticity using the univariate, IV model.

²⁵For comparison purposes, the OLS estimate of $\widehat{\varepsilon}_{OLS}$ is 1.0024.

Table 3: Parameter Values

Parameter	Value
(A) Obtained by Calibration	
Discount Factor (β)	0.985
Consumption Share (α)	0.685
Fixed Cost for Landlords (ϕ)	0.056
(B) Estimated by Instrumental Variables	
Housing Supply Elasticity (ε)	0.902 (0.171)

Note: Standard error in parentheses.

the simulated and empirical moments,

$$\hat{\Phi} = \arg \min_{\Phi} \sum_{k=1}^4 \left(m_k - m_k(\Phi) \right)^2, \quad (22)$$

where m_k represents the k -th moment in the data, and $m_k(\Phi)$ represents the corresponding simulated moment generated by the model. 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. Table 3 shows the three calibrated parameters, and Table 4 demonstrates that the model matches the empirical moments targeted in calibration well.

The four targeted moments are the homeownership rate, the landlord rate, the imputed rent-to-wage ratio ($\frac{rs}{w}$), 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 gross mortgage debt.²⁶ These households would be directly affected

²⁶The discount factor β governs household borrowing behavior in our model. Since deceased agents in our

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 gross mortgage debt	0.65	0.65

by the repeal of the mortgage interest deduction. According to data from the 1994-1998 American Housing Survey (AHS), approximately 65 percent of homeowners report gross mortgage debt balances.

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 Schlagenauf (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.

4 Properties of the Calibrated Baseline Model

Before using the model to evaluate counterfactual tax policies, it is important to show how the housing market and taxation operate in the baseline model. This section presents evidence

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 by households in our model economy.

Table 5: Moments not Targeted in Estimation

	Waves of the SCF			
	(1) 1998	(2) 2007	(3) 2010	(4) Model
Median House Value-to-Income Ratio	2.44	3.32	2.98	2.54
Median Loan-to-Income Ratio	0.58	0.91	0.93	0.78
Median Loan-to-Value Ratio	0.28	0.31	0.37	0.26

Notes: Columns 1-3 show statistics from the Survey of Consumer Finances. Column 4 shows statistics computed from the model.

on the ability of the model to match moments not targeted during estimation, examines the progressivity of the tax system, and discusses how housing tax expenditures are distributed across households.

4.1 Moments not Targeted in Estimation

As an external test of our model, we report several other key statistics generated by the model that were not targeted in the estimation. Table 5 compares frequently reported housing statistics generated by the model against cross-sectional moments computed from the 1998, 2007, and 2010 waves of the Survey of Consumer Finances (SCF).²⁷ Encouragingly, the moments—median house value-to-income, loan-to-income, and loan-to-value ratios—fall within the range of estimates computed from various waves of the SCF. Moreover, the median house value to income ratio for first-time home buyers generated by our model is 2.7, compared to 2.6 in the 2011 wave of the American Housing Survey (AHS), suggesting that first-time home-buyers in the baseline model are naturally buying the house relative to their income that matches the data. Finally, despite not having a full-fledged deterministic life cycle with explicitly modeled retirement, among retirement-age households (ages 61-70), 59 percent own a home without debt in the 2010 SCF data, compared to 53 percent in our model.

Turning to several relevant 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 plus 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 baseline house price-to-rent ratio in the model is 12.3, which is consistent

²⁷Appendix B shows how we compute these moments in the SCF data.

with U.S. data. 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 12.²⁸ Overall, the ability of our model to approximately replicate a number of key moments that were not targeted during calibration is encouraging.

4.2 Progressivity of Taxation in the Baseline Model

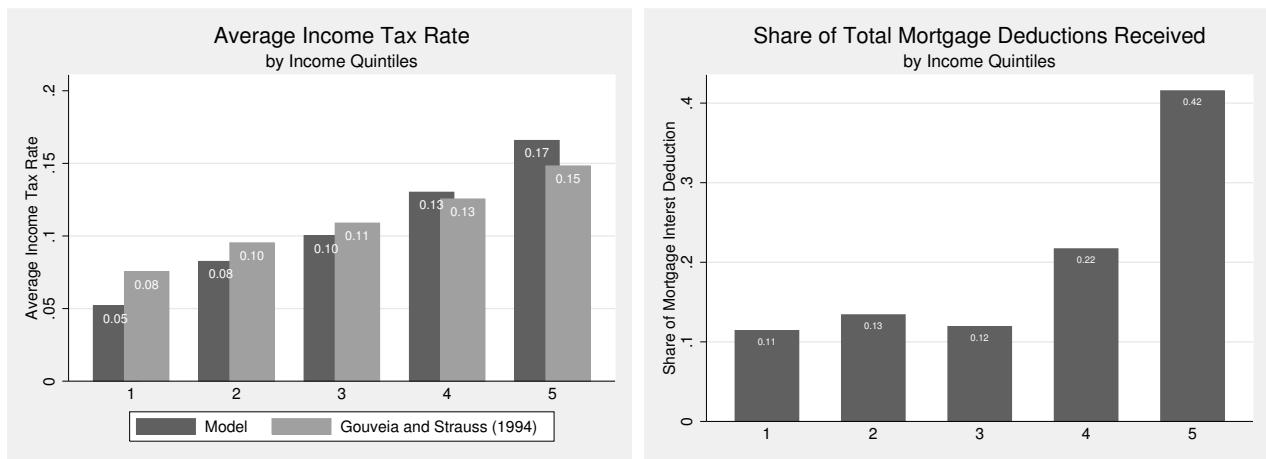
In this section, we compare the simulated progressivity of the tax system in the baseline model against the available data estimates. Gouveia and Strauss (1994) estimate the individual average tax rate (*atr*) as a function of total income using United States tax return data. The function is specified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

$$atr = \gamma - \gamma(\zeta y^\nu + 1)^{-1/\nu},$$

where y represents total income (in thousands of dollars), with parameters $\gamma = 0.258$, $\zeta = 0.031$, and $\nu = 0.768$ 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 (converted to dollars) and simulate the average tax rate of each household in the baseline economy using the Gouveia-Strauss tax function. 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).²⁹ Figure 1a 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.

²⁸There are many additional sources of data on the price-to-rent ratio. For example, the U.S. Department of Housing and Urban Development and the U.S. Census Bureau report a price-to-rent ratio of 10 in the 2001 Residential Finance Survey (chapter 4, Table 4-2). Davis et al. (2008) 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-to-rent ratio ranged between 18.8 and 20 between 1960 and 1995.

²⁹The 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 obligations.



(a) Average Income Tax Rates

(b) Share of Mortgage Interest Deductions

Figure 1: Tax Rates and Tax Deductions by Income Quintiles

4.3 Distribution of the Mortgage Interest Tax Deduction

Although mortgage interest deductions are in principal available to all homeowners, high income families in the U.S. benefit far more from these tax expenditures than low-income families.³⁰ Taxpayers with incomes of \$100,000 or more accounted for 11 percent of all tax returns but claimed more than 54 percent of the \$59 billion in mortgage interest deductions taken in the fiscal year of 2004 (JCT, 2010).³¹ Figure 1b shows the skewed distribution of homeowner mortgage interest tax deductions across income quintiles generated by the model. As in the data, the distribution of mortgage tax deductions is vastly uneven, with the top income quintile receiving roughly 40 percent of total mortgage interest tax deductions.

5 Repealing the Mortgage Interest Deduction

This section uses the model to simulate the effects of eliminating the mortgage interest deduction on equilibrium outcomes. We focus on the effects of this counterfactual tax reform on objects such as house prices, rents, homeownership, and household welfare. Section 5.1 compares the baseline economy to the new steady state equilibrium reached by the economy after the mortgage interest deduction is repealed. Having established the overall effects of

³⁰First, 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.

³¹On the other hand, taxpayers earnings up to \$30,000 account for 45 percent of all tax returns but less than 2 percent of total mortgage tax deductions.

the reform in the steady state, Section 5.2 turns to a detailed discussion of the dynamic transition path from the unexpected reform. The counterfactual experiment begins with the economy in the baseline steady state where mortgage interest is tax deductible. Starting from this initial steady state, the mortgage interest deduction is unexpectedly and permanently repealed. Along the perfect foresight transitional path that ends at the new steady state, all agents correctly forecast the sequence of house prices and rents, and markets clear in each period. Finally, Section 5.3 examines the effects of the reform on steady state tax revenue.

5.1 Steady State Outcomes

We start our analysis by exploring the effects of repealing the mortgage interest deduction on steady state housing market equilibrium. Mortgage tax deductions constitute the largest homeownership subsidy under the current tax code: the total tax expenditure toward mortgage interest in 2013 was estimated at \$90 billion (JCT, 2012).

In the baseline model, two distinct types of mortgage interest payments are tax deductible. 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 costs and property taxes) to offset gross rental income for tax purposes.³² Eliminating the mortgage interest deduction on rental space would tax landlords on gross rental income, rather than net. Thus, this section discusses the effects of eliminating the mortgage interest tax expenditure on owner-occupied space, while still allowing landlords to deduct mortgage interest payments on leased housing from their gross rental income when calculating taxable rental income.

Table 6 shows the effect of repealing the mortgage interest deduction for owner-occupied space. As the table illustrates, when the mortgage interest deduction is eliminated (column 2), house prices fall by 4.2 percent because, *ceteris paribus*, the cost of ownership has risen. At the same time, rent increases slightly, and the equilibrium house price-to-rent ratio decreases. Since house prices are now lower and ownership is now cheaper relative to renting, the homeownership rate rises from 65 percent to 70 percent.³³

³²The mortgage interest deduction available to landlords is not considered a tax expenditure because it follows the standard practice of allowing a business entity to deduct operating expenses from gross income when computing taxable income. In contrast, the deduction for mortgage interest on a residence is classified as a tax expenditure, because it is a reduction in income tax liability resulting from a “special” tax provision (JCT, 2010).

³³In this counterfactual experiment, the repeal of the mortgage interest deduction increases the aggregate

Table 6: The Effect of Eliminating the Mortgage Interest Tax Deduction

	(1) Baseline	(2) Experiment
House price	3.052	2.925
Rent	0.248	0.249
Price-rent ratio	12.320	11.715
Frac. homeowners	0.650	0.702
Fraction renter	0.350	0.297
Fraction owner-occupier	0.549	0.635
Fraction landlord	0.101	0.068
Median $\frac{\text{house value}}{\text{wage}}$	3.815	2.925
Fraction homeowners in debt	0.648	0.634
Average mortgage	2.815	1.931
Consumption equivalent variation (cev^*)	—	0.757%

Notes: Column (2) is the no-mortgage-deduction economy.

cev^* is the ex ante consumption equivalent variation.

The response of homeownership to the repeal of the mortgage interest deduction is determined by quantitative magnitude of two opposing forces. On the one hand, ceteris paribus, eliminating the mortgage interest deduction increases the after tax cost of homeownership for households with mortgages. On the other hand, the fall in equilibrium house prices works in the opposite direction, reducing the cost of homeownership. Specifically, the lower house price simultaneously (1) reduces down payments, $\theta qh'$, (2) shifts the price-to-rent ratio in favor of buying, and (3) reduces both entry and future per-period ownership costs that are proportional to the value of a home (i.e., transaction costs associated with buying, $\tau^b qh'$, as well as maintenance expenses and property taxes, $qh'(\tau^h + \delta^h)$). Our quantitative experiment demonstrates that, on balance, the numerous mechanisms stemming from the house price decline that encourage homeownership more than offset the impact of the lost mortgage interest deduction.

From the perspective of understanding the mechanisms generating the increase in homeownership, and the magnitude of the effect, the crucial households are those who rent in the baseline model. Broadly speaking, renters can be divided into two groups. Approximately one-third of renters are living hand-to-mouth in small apartments, with low wages, and zero savings. These severely credit constrained households cannot afford to purchase a house.

tax burden on households. Section 5.3 discusses the changes in tax revenue, and also conducts an alternative version of the reform that decreases income tax rates to achieve revenue neutrality. Quantitatively, the key results do not change significantly in the revenue neutral reform.

The remaining two thirds of renters are a more diverse group. On average, they earn close to the median wage, and have accumulated savings. Interestingly, the average member of this group could afford to purchase a house, but does not find it optimal to buy because the initial costs, $qh'(\theta + \tau^b)$, would consume all of their savings and the majority of their one-period labor income.³⁴

When the mortgage interest deduction is eliminated, the top 14 percent of renters in terms of wages and savings—who were on the margin of becoming homeowners—are induced to purchase homes by the drop in house prices. These households face relatively low marginal tax rates, so the loss of the discounted future tax benefits of the mortgage interest deduction are far outweighed by the drop in initial costs, $qh'(\theta + \tau^b)$, and the decrease in future per-period costs of ownership that are also proportional to house prices, $qh'(\tau^h + \delta^h)$. In addition, as shown in Table 6, households reduce mortgage debt when mortgage interest is no longer tax favored, which mitigates the impact of the lost deduction on the homeownership decision.

Unfortunately, it is difficult to validate the magnitude of this response to the counterfactual tax reform, largely because there is no consensus on the true elasticity of homeownership with respect to house prices, down payments, price-to-rent ratios, or other homeownership costs. As noted in Fuster and Zafar (2016), the major problem facing empirical work in this area is the absence of exogenous variation in key financial variables. However, Fuster and Zafar’s (2016) new work suggests that the responsiveness of homeownership to reduced down payments—one of the mechanisms at play in our paper—can be quite large. To circumvent the aforementioned endogeneity issues associated with the lack of exogenous variation in down payments, the authors conduct a novel survey designed to directly measure household willingness-to-pay (WTP) for owned housing. Reassuring, they find that renters’ WTP for owned housing increases sharply as minimum down payments decline, supporting our finding that renters on the margin of homeownership are quite responsive to the decline in house prices that accompany the repeal of the mortgage interest deduction. Of course, in our model, the response of homeownership is magnified relative to the hypothetical considered by Fuster and Zafar (2016), who focus on down payments. In our model, renters additionally respond to the lower price-to-rent ratio, as well as to a reduction in the entry costs and future

³⁴Depleting their liquid savings and using up most of their per-period income to buy a house is not an optimal choice for households who face uninsurable earnings shocks as well as sizable non-convex transaction costs associated with selling. Furthermore, as mentioned above, homeownership entails significant recurring costs in the form of maintenance expenses and property taxes.

per-period costs of homeownership.^{35,36}

5.1.1 Steady State Welfare Analysis

Interestingly, eliminating the mortgage interest deduction improves the steady state welfare of households. Following a large number of existing studies, steady state welfare is measured using the *ex ante* consumption equivalent variation, cev^* .³⁷ We define cev^* as the constant percentage change in per-period non-housing consumption, c , that equates the discounted *expected* sum of lifetime utility under the baseline tax system to that under the reformed system. As such, cev^* provides a quantitative answer to the question: Taking into consideration future earnings uncertainty, would you prefer to be born into a steady state economy with the mortgage interest deduction, or one without it? Measured in consumption equivalent units, welfare increases by 0.757 percent when the mortgage interest deduction is repealed (column (2) of Table 6). It is interesting to note that the reform improves welfare even though it slightly increases the total tax burden on households (total taxes increase by 0.60 percent).³⁸ Why are households better off on average even though their taxes have risen? Welfare rises because lower equilibrium house prices increase homeownership and housing consumption among low income households. These households have a relatively high marginal utility of shelter consumption, so shifting shelter consumption towards them increases aggregate welfare. In addition, average non-durable consumption increases by nearly 2 percent, in part because the repeal of the deduction lowers average household mortgage debt by 31 percent.

Figure 2 depicts the welfare improving shift in shelter consumption and ownership of housing that occurs when the mortgage interest deduction is repealed. The share of the housing stock owned by the top two quintiles of the wage distribution declines appreciably, because the after-tax cost of occupying mortgage-financed housing for households facing high marginal tax rates increases sharply. This housing is reallocated to households in the lower quintiles of the wage distribution. Lower equilibrium house prices make starter homes more

³⁵The response of homeownership in the model to decreases in the initial cost of owning is consistent with the findings of a number of related quantitative papers that study the effect of down payments on the housing market (Kiyotaki, Michaelides and Nikolov, 2011; Díaz and Luengo-Prado, 2008; Sommer, Sullivan and Verbrugge, 2013).

³⁶In addition, recent work by Bhutta and Keys (2016) and Mian and Sufi (2011) on home equity extraction supports the idea that new and marginal homeowners are in many cases credit constrained by downpayments.

³⁷See, for example, Hong and Ríos-Rull (2007) and Nakajima (2010).

³⁸Section 5.3 presents the exact changes in each type of tax revenue, and also presents a revenue neutral version of the reform in which income tax rates are decreased when the deduction is repealed.

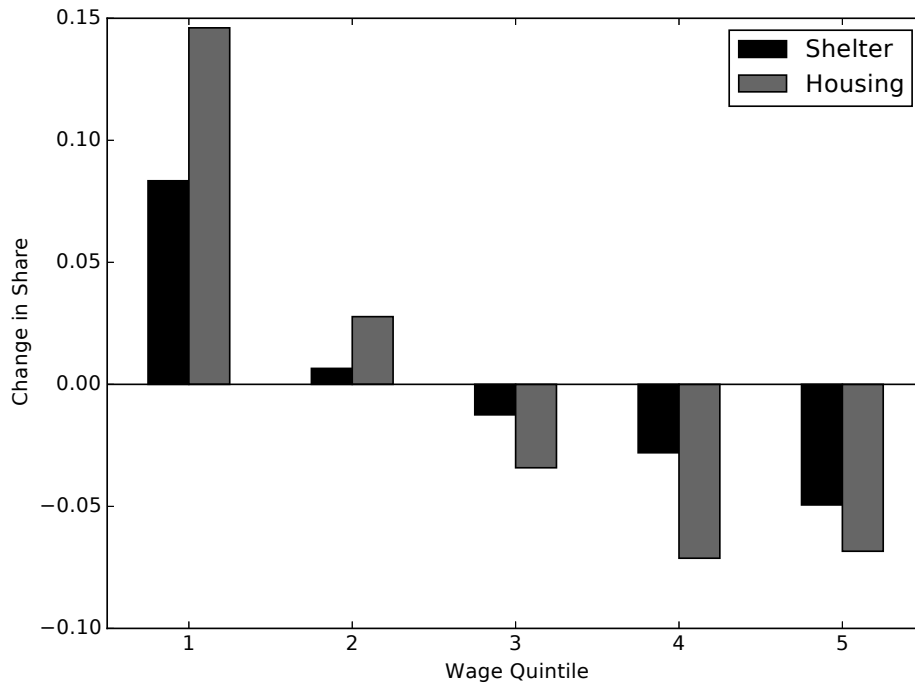


Figure 2: Percent Change in the Share of Steady State Shelter Consumption and Housing Ownership by Wage: Elimination of Mortgage Interest Deduction

affordable for previously credit constrained households at the bottom of the wage distribution, and also allow some middle income households to purchase larger houses. Qualitatively, the changes in the equilibrium allocation of shelter across wage quintiles mirror the changes in the allocation of housing, although the magnitudes of the changes are smaller.³⁹

5.2 Transitional Dynamics

Up to this point, the analysis has been confined to a comparison of two different steady state economies. This comparison reveals that eliminating the mortgage interest deduction—a hotly debated reform—improves overall welfare and increases homeownership. However, evaluating tax reform using only steady state analysis leaves many interesting and policy-relevant questions unanswered. In this section, we turn towards answering the question: What are the dynamic effects of suddenly, and unexpectedly, eliminating the mortgage interest deduction?

³⁹At the top quintiles of the wage distribution, the housing share is more responsive than shelter because some of the decrease in housing ownership consists of landlords selling rental property to previously credit constrained renters. At the bottom and middle quintiles of the wage distribution, housing is more responsive than shelter because rented shelter accounts for a sizable fraction of shelter consumption.

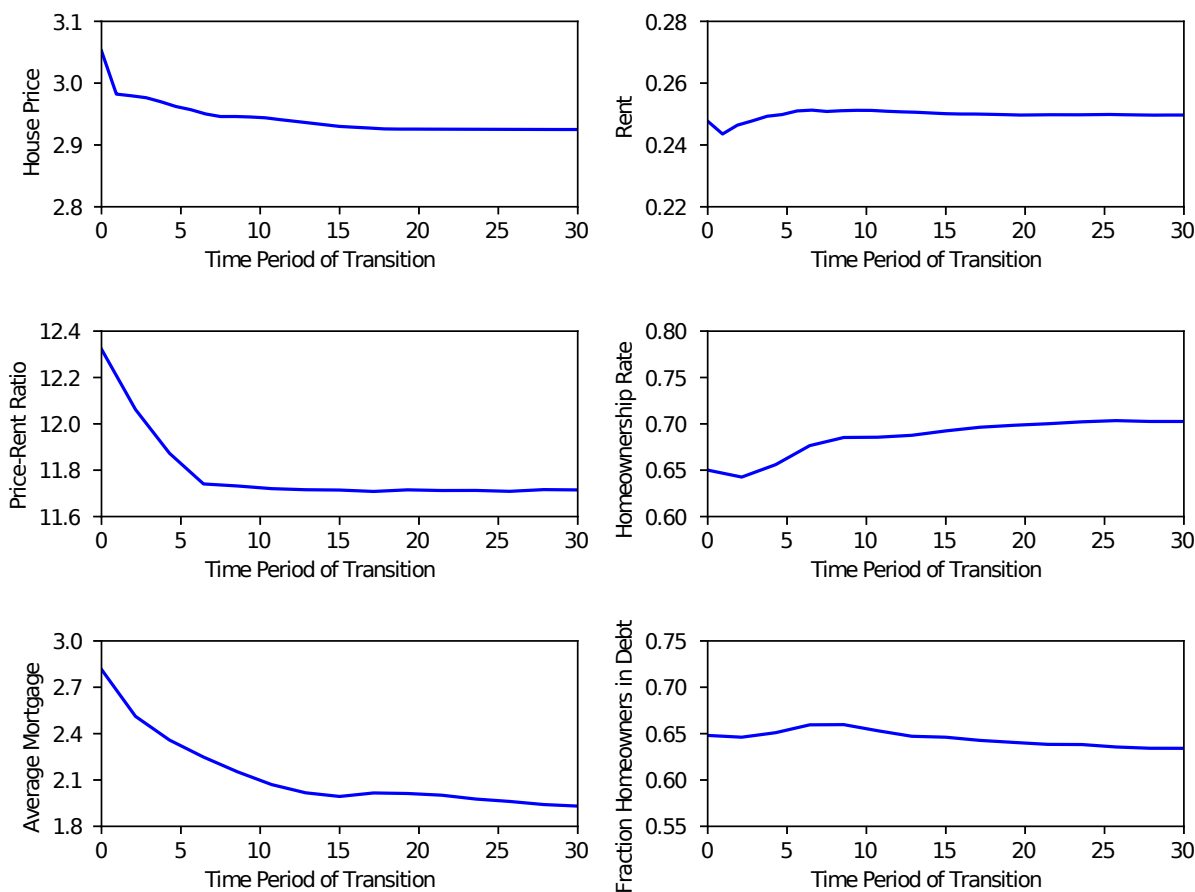


Figure 3: Transitional Dynamics of the Economy after Unexpected, Permanent Elimination of the Mortgage Interest Deduction at $t = 1$

5.2.1 Evolution of Aggregates Along the Transition

Figure 3 depicts the transitional dynamics of the economy after the unexpected, permanent elimination of the mortgage interest deduction.⁴⁰ When the reform is implemented, house prices immediately drop by 2.3 percent, and then smoothly decline to the new steady state equilibrium. The distinguishing feature of house price dynamics over the transition is that price adjustment occurs fairly rapidly: the initial price drop accounts for 56 percent of the total change in house prices observed over the 30 year transition. Within five years, fully 73 percent of the house price adjustment has taken place. At the same time, rents decline upon impact, even though—by the end of the transition—rents are slightly higher than their

⁴⁰Implementing an unexpected, complete policy change is standard in the quantitative literature. Of course, in actuality this type of reform may be to some extent anticipated by households. Similarly, the change could be phased in more gradually. Policy-makers could also consider compensation schemes to assist those harmed by reform.

pre-reform level. As a result, the house price-to-rent ratio falls rapidly and monotonically during the first five years of the transition and then gradually declines to its new steady state level.

Compared to the relatively rapid adjustment of house prices, homeownership converges more slowly, holding approximately constant for the first four years after the reform. After this initial sluggish response, the homeownership rate gradually rises from 65 to 70 percent. In terms of the speed of adjustment, 67 percent of this increase occurs within 10 years of the reform. There are two reasons why homeownership responds gradually to the elimination of the mortgage interest deduction. Although the initial decrease in house prices makes ownership more attractive, the simultaneous drop in market rent lessens the incentive for renters to immediately move into homeownership. At the same time, forward-looking renters realize that house prices will continue to fall in the future, even as rents rise, so buying a home later will only become more attractive.

Why does over half of house price adjustment occur immediately when the mortgage interest deduction is repealed? The answer is that the price of a durable good, such as housing, is set at the margin by households who are transacting in the market. When the mortgage interest deduction is suddenly eliminated, households who are on the margin of buying a house—either as a first time buyer, or to upsize—immediately reduce their demand for housing because, *ceteris paribus*, the after-tax cost of owner-occupying a square foot of mortgage-financed housing has risen. Demand by these “transacting households” thus drops discretely. At the same time, the existence of sizable transaction costs prevents existing homeowners from offloading their properties *en masse* in order to move to smaller houses, meaning that the amount of housing for sale stays relatively unchanged in the first period of the transition.⁴¹ As a result, house prices drop significantly as soon as the reform is implemented.

Turning to rent dynamics, with the after-tax cost of occupying square foot of mortgage-financed housing suddenly higher, in a frictionless world, existing homeowners with mortgages would prefer to own a smaller house. However, in our economy, lumpy transaction costs prevent most of these homeowners from immediately selling their houses and downsiz-

⁴¹Clearly, homeowners without mortgage balances have no direct incentive to alter their holdings of housing (h'), because they are not directly affected by the repeal of the mortgage interest deduction (although they are affected indirectly by capital losses after the reform is implemented).

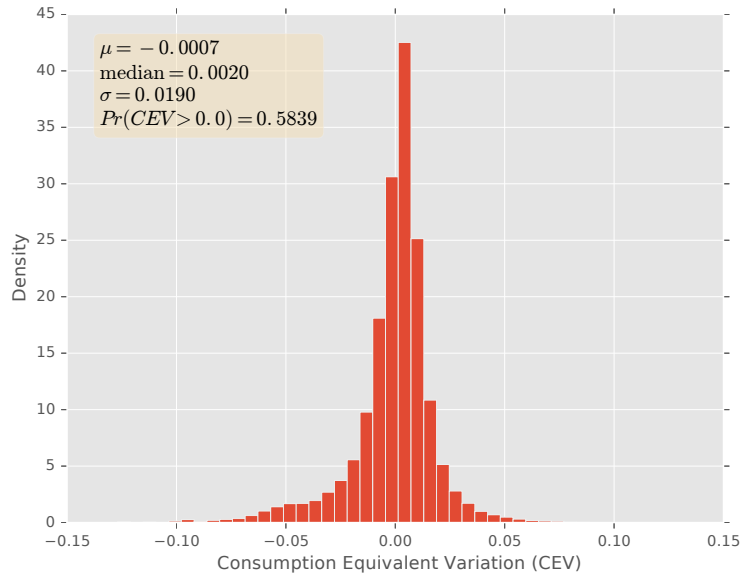


Figure 4: Histogram of Consumption Equivalent Variation ($cevi$)

ing. Instead, some homeowners choose to reduce housing consumption by leasing out some of their now unwanted property on the rental market. This immediate outward shift in the supply of rental property causes rents to fall in the first period of the transition. Over time, as households adjust to the new tax regime, rental supply contracts, and rents converge to their new equilibrium level.

The bottom panels in Figure 3 show that there is an interesting trend in mortgage borrowing over the transition as markets adjust to the tax reform. The elimination of the tax favored status of mortgages, acting in concert with the fall in equilibrium house prices, causes households to reduce mortgage borrowing. On the intensive margin, as the bottom left panel shows, the average mortgage balance declines by 31 percent over the transition between steady states.⁴² On the extensive margin, the bottom right panel shows the evolution of the fraction of households with outstanding mortgage debt. This fraction initially increases marginally as renters transition into homeownership, before declining to the slightly lower equilibrium level by the end of the transition. Taken together, the results show that much of the response of household borrowing to the elimination of the tax favored status of mortgages occurs on the intensive, rather than the extensive, margin.

⁴²Gervais and Pandey (2008) posit that the elimination of the tax favored status of mortgages would lead to reshuffling of household portfolios away from mortgage debt.

5.2.2 Welfare Analysis Along the Transition

We quantify welfare gains and losses along the transition path using a measure that captures the differential impact of the unexpected elimination of the mortgage interest deduction on households who are heterogeneous in terms of housing ownership (h'), financial assets (d', m'), and labor earnings (w) at the time of the reform. The welfare impact of the tax reform for each person i alive at the time of the reform is measured by the *ex post* consumption equivalent variation, cev_i . We define cev_i as the constant percentage change in per-period non-housing consumption, c , that equates the discounted sum of lifetime utility *realized* under the baseline tax system to that under the reformed system. As such, for each household alive at the time of the reform, cev_i provides a quantitative answer to the question: If you had perfect knowledge of the future, would you prefer to experience the tax reform, or not?

Figure 4 shows the distribution of cev_i across households who are alive when the mortgage interest deduction is eliminated. The reform leads to a median welfare gain of 0.20 percent. Moreover, 58 percent of households experience an improvement in their lifetime welfare. However, welfare effects vary widely across the population: a household at the 5th percentile experiences a 3.7 percent welfare loss, while a household at the 95th percentile experiences a 2.3 percent welfare gain.

Since the welfare effects of the tax reform vary widely across the population, it is important to identify the distinguishing features of households that enjoy welfare gains compared to those that incur welfare losses. Table 7 shows that there are systematic differences in housing tenure, mortgage status, and labor income between winners and losers from the reform.⁴³ In particular, renters, and those without mortgage debt at the time of the reform, tend to enjoy welfare gains while landlords and high income households with mortgages experience the largest welfare losses.

The top section of Table 7 summarizes welfare along the transitional path conditional on homeownership status at the time of the reform. The simulations show that 59 percent of renters benefit from the reform over their lifetime, experiencing a mean welfare gain equal to 0.40 percent of future consumption. On average, renters benefit from the elimination of the mortgage interest deduction for several reasons. Market rent drops suddenly along the transition path (Figure 3), so renters immediately enjoy a lower cost of shelter. At

⁴³Throughout this section, unless it is explicitly stated to the contrary, welfare effects are conditioned on the households state immediately before the tax reform is implemented (time period zero in Figure 3).

Table 7: Summary Statistics: Welfare Over the Transition

	$\mu(cev_i)$	$\sigma(cev_i)$	Fraction $cev_i > 0$
<hr/>			
Initial housing tenure			
Renter	0.004	0.015	0.589
Occupier	0.001	0.015	0.655
Landlord	-0.027	0.027	0.184
All	-0.001	0.019	0.584
Initial mortgage			
Have mortgage	-0.005	0.020	0.547
No mortgage	0.002	0.020	0.663
Initial wage			
Wage top 15%	-0.009	0.029	0.539
Wage at median	0.001	0.015	0.639
Wage bottom 15%	0.001	0.014	0.531

Notes: cev_i refers to the ex-post consumption equivalent variation. $\mu(cev_i)$ and $\sigma(cev_i)$ represent the mean and standard deviation.

the same time, renters do not hold mortgages, so their current income tax obligations are not affected by the elimination of the deduction. Most importantly, the welfare gains of households who rent at the time of the reform are driven by the decline in house prices over the transition. Lower house prices, through their effect on down payments and other costs of homeownership, allow renters to attain homeownership earlier than they would in the baseline economy where mortgage interest was tax deductible. In addition, lower house prices over the life cycle allow some households to eventually upgrade to larger homes that would have been unaffordable before the repeal of the deduction.

At the opposite end of the welfare spectrum, over 80 percent of households who are landlords at the time of the reform are harmed by its implementation. The average cev_i for landlords is -2.7 percent, indicating that, on average, landlords are significantly worse off after the reform. Landlords are overwhelmingly harmed by the reform for a number of reasons. First, landlords tend to be high lifetime income households who occupy relatively large houses. The high shelter consumption of landlords tends to be financed by debt, so landlords are directly and highly adversely affected by the higher tax obligations created by the elimination of the mortgage interest deduction.⁴⁴ The negative impact of eliminating

⁴⁴As explained in Section 5.1, the mortgage interest deduction experiments only eliminate the deduction on owner-occupied housing. Landlords are always allowed to deduct the business expense of mortgage interest paid on rental property.

the deduction on landlords is further bolstered by progressive taxation, because landlords tend to face high marginal tax rates that make the deduction disproportionately valuable to them. In addition to welfare losses arising directly from the loss of the deduction, landlords incur sizable capital losses on their large property holdings due to the fall in house prices. Furthermore, since landlords typically already own large properties at the time of the reform, there is very limited scope for them to benefit from the house price decline by purchasing a newly affordable, larger house for their own consumption.

It remains to discuss the effect of repealing the mortgage interest deduction on the welfare of owner-occupiers, who account for the majority of the population. The effects on this group lie in between the two extremes experienced by renters and landlords. However, Table 7 shows that 65 percent of occupiers gain from the reform, so the experience of owner-occupiers over the transition resembles that of renters more closely than that of landlords. This is the case because owner-occupiers tend to live in smaller houses than landlords, so the majority of them benefit from the house price declines associated with reform. For these households, the increased affordability and accessibility of bigger homes outweighs the adverse effects of the house price decline and the removal of the option to claim the mortgage interest deduction.

The mean welfare gain for owner-occupiers of 0.10 percent indicates that although 65 percent of these households benefit from the reform, quantitatively the reform is close to welfare-neutral for the average member of the group. However, the overall mean cev_i masks considerable heterogeneity within the group: the average occupier who benefits from the reform experiences a welfare gain of 0.85 percent, while the average occupier who is harmed by the reform incurs a welfare loss of 1.2 percent. The greatest welfare losses accrue to high-income occupiers who live in large homes, have large mortgages, face high marginal tax rates, and in many ways resemble landlords. This point is illustrated in Figure 5, which shows that households with the largest mortgages at the time of the reform (Quintile 1) are subjected to a 2.9 percent welfare loss by the elimination of the mortgage interest deduction. Owner-occupiers who benefit from the reform are at the other end of the spectrum: they live in more modest homes, have smaller mortgages, and face lower marginal tax rates.

A number of different mechanisms are operating on all households who are owner-occupiers at the time of the transition. First, similar to renters, some of these households benefit from the downward trend in house prices over the transition path because it makes

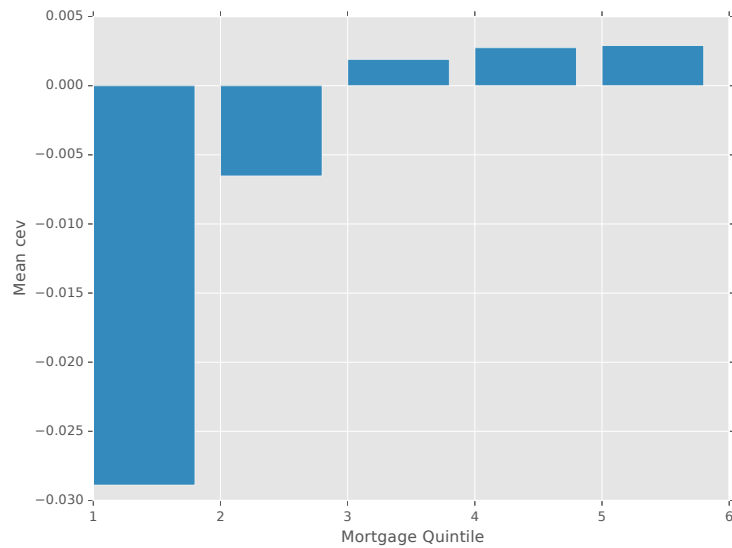


Figure 5: Mean Consumption Equivalent Variation (cev_i) by Initial Mortgage Quintile

Notes: Quintile 1 represents the largest mortgages.

upward moves to larger houses possible.⁴⁵ Second, the sudden house price decline generates capital losses. Third, owners with mortgages lose the mortgage interest deduction, which increases the carrying cost of financed shelter. Fourth, all households, even those currently without mortgages, lose the option value of claiming the mortgage interest deduction in the future. For any given household, whether the overall welfare effect is positive or negative is a quantitative question about the magnitudes of these, in some cases opposing, forces. The simulations reveal that the majority of households with mortgages (55 percent) still benefit from the reform, even though they immediately lose a tax deduction and incur a capital loss. Indeed, Figure 5 shows that it is only households in the top two quintiles of the mortgage distribution who are, on average, harmed by the reform.

The preceding discussion of the transition path of the economy has focused on variation in welfare effects across households who occupy different states at the time of the reform. However, the path that a household takes after the reform also has a large impact on cev_i . Figure 6 shows how the initial state and post-reform path interact to determine the welfare impact of the elimination of the mortgage interest deduction. For the purposes of the figure, the initial state is summarized by the mortgage balance at the time of the reform, and the post-reform experience is measured by lifetime income. The bottom left corner of the figure

⁴⁵Section 5.1 explains how the elimination of the mortgage interest deduction interacts with progressive taxation to produce a welfare-improving shift of housing from high income to low income households.

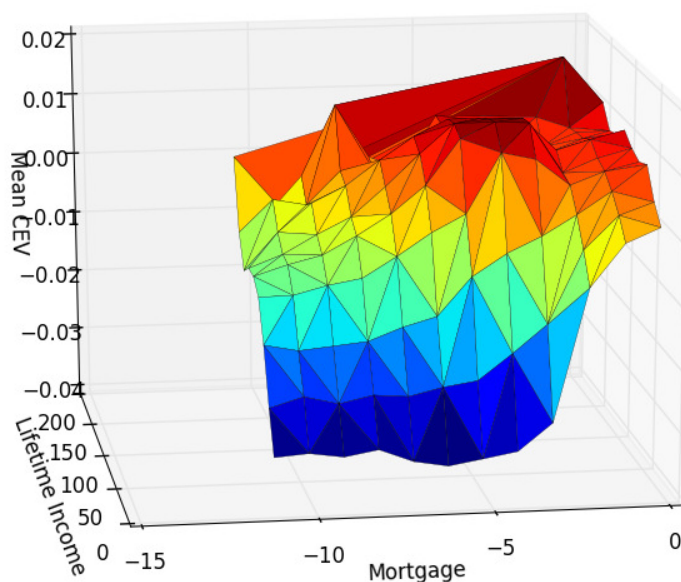


Figure 6: Mean Consumption Equivalent Variation (cev_i) by Initial Mortgage and Lifetime Income

shows that the households most adversely affected by the reform have large mortgages at the time of the reform, and then go on to earn low lifetime incomes over the transition. These unfortunate households face significant tax increases when their mortgage interest payments are no longer deductible, and are burdened by large mortgages on houses that have suddenly depreciated in value. The adverse effects persists over time, because low lifetime income households are unable to quickly pay down their mortgages. The figure also shows that the negative welfare effects on households with mortgages become less severe as lifetime income rises. Ceteris paribus, higher lifetime income over the transition allows households to pay down their mortgages, which are no longer favored by the tax code. The far right edge of Figure 6 shows that the cev sharply increases as the household mortgage at the time of the reform reaches low levels. This result is consistent with the preceding discussion of the relationship between initial mortgage and the cev_i . Interestingly, across the entire range of lifetime income shown in Figure 6, households without initial mortgages benefit from the reform. Overall, the households who realize the largest welfare gains are those who have small or zero mortgage balances at the time of the reform, and also are fortunate enough to

Table 8: Revenue Neutral Experiment: Eliminating the Mortgage Interest Tax Deduction

	Eliminate MID		
	(1) Baseline	(2) Experiment	(3) Revenue Neutral
House price	3.052	2.925	2.931
Rent	0.248	0.249	0.250
Price-rent ratio	12.320	11.715	11.715
Frac. homeowners	0.650	0.702	0.702
Consumption equivalent variation (cev^*)	—	0.757%	0.786%
% Δ income tax revenue	0.000	2.596%	1.806%
% Δ property tax revenue	0.000	-7.798%	-7.614%
% Δ total tax revenue	0.000	0.598%	0.000%

Notes: Column (2) is the counterfactual no-mortgage-interest deduction economy.

Column (3) is the revenue neutral no-mortgage-interest deduction economy.

cev^* is the ex ante consumption equivalent variation.

% Δ indicates percent change relative to baseline model.

earn relatively high incomes in the post-reform periods. These households are best positioned to take advantage of lower house prices by purchasing bigger houses than they would have been able to afford in a world where mortgage interest was tax deductible.

5.3 Tax Revenue and Repeal of the Mortgage Interest Deduction

This section discusses the effects of repealing the mortgage interest deduction on tax revenue, and presents a revenue neutral version of the reform. Column (2) of Table 8 shows how steady state tax revenue changes when the mortgage interest deduction is repealed.⁴⁶ On the one hand, the reform leads to a 2.6 percent increase in *income* tax revenue because taxable income rises when mortgage interest is no longer deductible. There are two mechanisms behind the observed increase in taxable income. First, taxable income rises because total deductions (ψ) fall. Second, the decline in equilibrium house prices reduces the level of property tax deductions; thus further decreasing the total deductions available to households and thereby re-enforcing the increase in taxable income. On the other hand, *property* tax revenue falls by 7.8 percent because of the decline in equilibrium house prices. In aggregate, the increase in income tax revenue is nearly offset by the sharp drop in property tax revenue, so *total* tax revenue rises slightly by approximately one-half of a percentage point.

Column (3) of Table 8 presents a revenue neutral version of the repeal of the mortgage

⁴⁶The results of this reform, excluding the tax revenue effects, were previously presented in Table 6.

interest deduction. In this experiment, income tax rates are reduced across-the-board so that total tax revenue remains at the baseline level when the mortgage interest deduction is removed. A slight reduction in tax rates of less than one percent is sufficient to achieve revenue neutrality. The increase in household after-tax income causes both rents and house prices to increase slightly relative to the non-revenue neutral reform shown in Column 2. Since the change in house prices is small, and the price-rent ratio remains unchanged, homeownership is essentially unchanged relative to the non-revenue neutral tax reform (Column 2). The revenue neutral experiment is only a marginal welfare improvement over the non-revenue neutral experiment, as the welfare measure (cev^*) increases from 0.757 percent to 0.786 percent. While the increase in disposable income makes households better off, this welfare benefit is offset to some extent by the accompanying increases in house prices and rents.

6 Conclusion

Each year, the mortgage interest deduction reduces U.S. Federal tax revenue by over \$90 billion. This lost revenue amounts to approximately 7 percent of total personal income tax payments. In the ongoing debate over budget deficits and fiscal reform, eliminating the mortgage interest deduction has been a frequently discussed policy change. Proponents of reform point out that the mortgage interest deduction reduces government revenue, is a regressive tax policy, and subsidizes household mortgage debt.

However, there are many unanswered questions about the effects of eliminating the mortgage interest deduction on the housing market. In this paper, we build a model that focuses on understanding, and quantifying, the effects of tax reform on equilibrium house prices, rents, homeownership, and welfare. Although opponents of tax reform claim that repealing the deduction would reduce homeownership, whether or not this is true is ultimately a quantitative question about the magnitude of the resulting equilibrium change in the after-tax cost of homeownership. *Ceteris paribus*, repealing the mortgage interest deduction increases the cost of financing housing, thereby reducing homeownership. However, our model shows that in equilibrium, house prices fall, allowing credit constrained renters to become homeowners. Moreover, the price-to-rent ratio falls, shifting relative prices in favor of owning. Given the progressive nature of the U.S. income tax code, the results also show that in addition to

increasing homeownership, eliminating the mortgage interest deduction shifts housing consumption from high-income to lower-income households, thereby increasing expected lifetime welfare.

The impact of unanticipated tax reform on the welfare of households who are *alive* at the time of the reform (and therefore made decisions about homeownership and mortgage debt under the original tax code) is another significant policy concern. We study this issue by examining the transitional dynamics of the housing market after the sudden repeal of the mortgage interest deduction. As far as social welfare, 58 percent of households alive at the time of the reform are better off under the reformed tax code. However, welfare effects vary widely across the population depending on a household's state at the time of the reform. In particular, homeowners with large mortgages and high incomes frequently incur large welfare losses over their lifetimes.

Finally, our paper is silent on the political feasibility of tax reform, although this is certainly an important and timely additional question. On aggregate, our model suggests that households benefit from tax reform. However, the benefits are largest for young, low-income households, while the costs tend to be highest for older, high-income households. In addition, interest groups representing the real estate industry spend millions of dollars lobbying Congress each year, and these groups strongly support the *status quo* tax regime. Taken together, these facts perhaps cast some doubt on the feasibility of reform, but we leave this as an interesting question for future research.

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7 Appendix A: Solving the Model (For Online Publication)

7.1 Finding Equilibrium in the Housing and Rental Markets

Equilibrium in the housing and rental markets is formally defined by the conditions presented in Section 2.7. 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

$$\sum_{i=1}^N h'_i(q^*, \rho^* | x) = H \quad (23)$$

$$\sum_{i=1}^N s'_i(q^*, \rho^* | x) = H. \quad (24)$$

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.

7.2 The Algorithm

Let q_k represent the k th 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

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

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

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

$$ED_k^h(q^*, \rho^*) = 0 \quad (27)$$

$$ED_k^s(q^*, \rho^*) = 0. \quad (28)$$

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 $ED_k^s(q_k, \rho_k(q_k))$.
 - (a) If $ED_k^s(q_k, \rho_k(q_k)) < 0$ 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 $ED_k^s(q_k, \rho_k(q_k)) < 0$ because $ED_k^s(q_k, \rho_k(q_k))$ is decreasing in q_k .
 - (b) If $ED_k^s(q_k, \rho_k(q_k)) > 0$ set $k = k + 1$ and $q_{k+1} = q_k + \varepsilon$ and go to step (2).
 - (c) If $ED_k^s(q_k, \rho_k(q_k)) = 0$, the equilibrium prices are $q^* = q_k$, $\rho^* = \rho_k(q_k)$, so stop.

8 Appendix B: SCF Data (For Online Publication)

The 1998, 2007, and 2010 waves of the Survey of Consumer Finances (SCF) are 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 $y = w + rd' + TRI - \tau^{LL}q(h' - s)$. Data and the SAS code are available upon request, but both can be also found at the SCF website.

9 Appendix C: Sensitivity Analysis (For Online Publication)

9.1 Risk-free Interest Rate

Table 9 shows the sensitivity of our results to a fifty percent reduction in the risk-free interest rate r , from 4 percent to 2 percent. Since the mortgage interest rate r^m is determined by a constant markup, κ , over r , changes in r directly translate into change in r^m . Hence, changes in r affect both the cost of borrowing and the return on savings.

Before considering the question of how the level of the interest rate affects the predictions of the model with regard to tax reform, it is useful to examine how the interest rate affects the model under the baseline tax system. Columns 1 and 3 in Table 9 describe the steady state economies where $r = 0.04$ and $r = 0.02$, under the baseline tax system where the mortgage interest deduction (MID) is available. When r is lowered from 4 percent to 2 percent, the house price level rises by approximately 16 percent, the rent falls by 1.6 percent, and the price-to-rent ratio rises by 17 percent from its baseline value of 12.3.⁴⁷ At the same

⁴⁷The simulated interest rate elasticity of house prices from the model is consistent with recent empirical

Table 9: The Effect of Eliminating the Mortgage Interest Tax Deduction under Alternative Level of the Interest Rate

	(A) Baseline Model ($r = 0.04$)		(B) Lower Interest Rate ($r = 0.02$)	
	(1) Baseline	(2) Eliminate MID	(3) Baseline	(4) Eliminate MID
House price	3.052	2.925	3.530	3.459
Rent	0.248	0.249	0.245	0.242
Price-rent ratio	12.320	11.715	14.399	14.281
Frac. homeowners	0.650	0.702	0.642	0.646
Fraction renter	0.350	0.297	0.357	0.354
Fraction owner-occupier	0.549	0.635	0.541	0.542
Fraction landlord	0.101	0.068	0.102	0.103
Median $\frac{\text{house value}}{\text{wage}}$	3.815	2.925	3.705	3.630
Fraction homeowners in debt	0.648	0.634	0.904	0.900
Average mortgage	2.815	1.931	3.739	3.514
cev^*	—	0.757%	—	0.732%

Notes: Columns (1) and (3) are the baseline tax system, under $r = 0.04$ and $r = 0.02$.

Columns (2) and (4) are the no-mortgage deduction economies, under $r = 0.04$ and $r = 0.02$.

cev^* is the ex ante consumption equivalent variation.

time, homeownership rate falls slightly from its baseline level of 65 percent to 64.2 percent. The mechanisms generating these equilibrium responses are discussed in detail in Sommer, Sullivan and Verbrugge (2013), which studies how interest rates affect equilibrium house prices, rents, and homeownership.⁴⁸ By way of summary, a lower interest rate reduces the cost of mortgage borrowing as well as the rate of return to the alternative investment, deposits. Both effects increase demand for owned housing, causing house prices to rise. At the same time, there is a portfolio shift: rental property investment becomes relatively more attractive as borrowing costs and the returns to deposits fall.

Two opposing forces produce the slight decline in homeownership from 65 percent when $r = 0.04$ to 64.2 percent when $r = 0.02$. On the one hand, the 200 basis point drop in r lowers the cost of borrowing for aspiring homeowners, making housing investment relatively more affordable. On the other hand, the equilibrium increase in house prices increases down payments, and the lower deposit rate makes it more difficult for prospective buyers to save up for a downpayment. Moreover, with house prices now substantially higher, larger loan amounts are needed to finance housing purchases—the size of the average mortgage rises by nearly 30 percent when r is reduced to 2 percent from 4 percent. On net, these countervailing

evidence in Glaeser, Gottlieb and Gyourko (2010).

⁴⁸This paper does not incorporate progressive taxation or study the effect of the mortgage interest rate deduction on the housing market.

forces associated with the reduction in r approximately offset, resulting in a homeownership rate that is roughly comparable between the two economies.

Columns 2 and 4 in Table 9 depict the $r = 0.04$ and $r = 0.02$ economies when the mortgage interest rate deduction is repealed. When the deduction is repealed, the house price and the price-to-rent ratio decline in both models, but the declines are relatively less pronounced when $r = 0.02$. Whereas the house price and the price-to-rent ratio fall by approximately 4 and 5 percent when the deduction is repealed in the $r = 0.04$ economy, they decline by only 2 and 0.1 percent when $r = 0.02$. The forces driving the decline in the house price in both economies are as discussed in Section 5.1: the repeal of the mortgage interest deduction decreases house prices because, *ceteris paribus*, the after-tax cost of occupying a square foot of housing has risen.

Mirroring the house price effect, the response of homeownership to the repeal of the deduction when $r = 0.02$ is also somewhat muted relative to the $r = 0.04$ economy. This is the case because house prices are significantly higher in the low-interest rate economy. Even though house prices decline after the tax reform, the 2 percent drop in house prices from the significantly higher initial level is insufficient to lower down payment requirements for marginal homeowners to the point where they can afford to become homeowners, all else constant. Moreover, given the significantly lower savings rate, it also takes aspiring homeowners longer to save for a downpayment. Finally, the relative price of homeownership (as captured by the price-to-rent ratio) is almost unchanged after the tax reform when $r = 0.02$, as opposed to the nearly 5 percent decline when $r = 0.04$. As a result, when the deduction is repealed, the homeownership rate rises by 0.4 percentage points in the economy where $r = 0.02$; significantly less than the nearly 5 percentage point increase in the economy where $r = 0.04$.

Importantly, the elimination of the mortgage interest deduction improves welfare in both the high and low interest rate economies. The MID is highly distortionary, even when the interest rate is low, because of the inverse equilibrium relationship between house prices and the interest rate which causes house prices to be significantly higher when rates are low. Mortgage debt rises with house prices: Columns 1 and 3 in Table 9 show that under the baseline tax system, average mortgage debt is 33 percent higher when $r = 0.02$, and fully 90 percent of homeowners are in debt (compared to 65 percent under a 4 percent interest rate). As a result, eliminating the MID has large welfare effects at both levels of the interest rate.

It is interesting to note that the magnitude of the welfare improvement is quite similar at both interest rate levels, even though the homeownership response is much smaller when $r = 0.02$ (columns 2 and 4 of Table 9). Why is this the case? The answer is that the main mechanism generating the welfare gain—the redistribution of housing from the wealthy to low income households—is still in effect when the interest rate is low. Specifically, under the baseline interest rate of 0.04, when the mortgage interest deduction is repealed, housing is re-allocated from high-income households (the main beneficiaries of the deduction) to low-income households, some of whom are induced to enter homeownership by the decline in the house price and the lowered price-to-rent ratio. In the alternative scenario where $r = 0.02$, the elimination of the MID leads to a similar re-allocation of housing from high to low income households. However, since house prices are much higher when $r = 0.02$, and the drop in house prices is smaller, the reallocation of housing primarily takes place on the intensive margin: relatively low income homeowners purchase larger houses, while high income households downsize.

9.2 Risk Aversion Parameter

The baseline calibration assumes that the risk aversion parameter, σ , equals 2.5. Table 10 shows how setting the risk aversion coefficient to a lower value ($\sigma = 1.5$) affects the model. Specifically, the table shows steady state summary statistics for the baseline tax system and the counterfactual tax system under the two different levels of risk aversion.

The combination of non-convex transaction costs and idiosyncratic income risk in the model implies that when the risk aversion coefficient is lowered, the demand for housing rises, all else equal. Comparing columns 1 and 3 of Table 10 shows that the increase in demand causes house prices to rise (by 3.5 percent) and induces households to increase borrowing (the average mortgage rises by over 20 percent). At the same time, higher house prices are passed through into rents by landlords, so the price-rent ratio remains essentially unchanged. Given that house prices are higher and the relative cost of owning is unchanged when $\sigma = 1.5$, the homeownership rate falls by 1.3 percentage points, from 65 percent in the baseline model to 63.7 percent in the model where $\sigma = 1.5$.

When the mortgage interest deduction is repealed, house prices and the price-to-rent ratio fall under both levels of risk aversion (columns 2 and 4). Under the baseline level of

Table 10: The Effect of Eliminating the Mortgage Interest Tax Deduction under Alternative Level of Risk Aversion

	(A) Baseline Model ($\sigma = 2.5$)		(B) Lower Risk Aversion ($\sigma = 1.5$)	
	(1) Baseline	(2) Eliminate MID	(3) Baseline	(4) Eliminate MID
House price	3.052	2.925	3.161	3.066
Rent	0.248	0.249	0.257	0.261
Price-rent ratio	12.320	11.715	12.297	11.756
Frac. homeowners	0.650	0.702	0.637	0.703
Fraction renter	0.350	0.297	0.362	0.297
Fraction owner-occupier	0.549	0.635	0.536	0.623
Fraction landlord	0.101	0.068	0.101	0.080
Median $\frac{\text{house value}}{\text{wage}}$	3.815	2.925	3.952	3.218
Fraction homeowners in debt	0.648	0.634	0.723	0.698
Average mortgage	2.815	1.931	3.414	2.534
cev^*	—	0.757%	—	0.928%

Notes: Columns (2) and (4) are the no-mortgage deduction economy.
 cev^* is the ex ante consumption equivalent variation.

risk aversion, the repeal of the MID increases homeownership from 65 percent to 70 percent (columns 1 and 2). Under the lower level of risk aversion, the quantitative response of homeownership to the repeal is slightly larger, as homeownership increases from 64 percent to 70 percent (columns 3 and 4). The reform improves welfare ($cev^* > 0$) under both levels of risk aversion. Mirroring the responses of homeownership, the welfare gain is somewhat larger in the lower risk aversion economy.

9.3 Distribution of Housing

Given the discreteness of the housing choice, and the role of down payment constraints in our model, it is interesting to explore the distribution of renters and homeowners across house sizes. Specifically, one might be interested to know whether renters are disproportionately clustered at the smallest rental unit that is not available for purchase, \underline{s} . As the first column in Table 11 illustrates, about 45 percent of renters in the model occupy the smallest size unit that is not available for ownership, \underline{s} , while an additional 53 percent of renters occupy the next house size, $h(1)$, which is available for purchase. The remaining 2 percent of renters are dispersed across the larger house sizes.

Turning to homeowners, the second column in Table 11 shows the distribution of homeowners across shelter sizes. While over 90 percent of homeowners occupy house sizes $h(1)$ – $h(4)$, nearly 10 percent of homeowners occupy larger housing units.

Table 11: The Distribution of Shelter Consumption for Renters and Homeowners

Size	Homeownership Status	
	(1) Renter ($h' = 0$)	(2) Owner ($h' > 0$)
\underline{s}	45.1	0.0
$h(1)$	53.5	17.6
$h(2)$	0.5	54.6
$h(3)$	0.01	13.3
$h(4)$	0.00	5.6
$\geq h(5)$	0.9	8.9

Notes: Entries are percentages (%).