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Abstract

We study the effects of government intervention in the housing market on prices, quantities and welfare in a general equilibrium model with heterogeneous agents. We consider (i) the introduction of temporary home purchase tax credits and (ii) a removal of the asymmetric tax treatment of owner-occupied and rental housing. Home buyer tax credits temporarily raise house prices and transaction volumes, but have negative welfare effects. Removing the asymmetric tax treatment of owner-occupied and rental housing generates welfare gains for a majority of agents in a comparison of stationary equilibria. Welfare impacts are more varied, though still positive, along the transition between steady states.

1 Introduction

Increasing homeownership has been a U.S. policy goal for decades, and a number of tax rules and regulatory efforts have been directed at raising the affordability and attractiveness of owner-occupied housing. Government interventions in the housing market come in many forms. Mortgage interest rates are subsidized through Fannie Mae, Freddie Mac and Ginnie Mae. The tax code favors owner-occupied over rental housing by exempting imputed rents on owner-occupied housing from income taxation. Capital gains on real estate are not fully taxed. Moreover, property owners can deduct mortgage interest payments from their taxable income. This is true both for owner-occupiers and for landlords who can deduct mortgage interest payments as a business expense. In addition, the U.S. government has recently employed a number of short-term incentives to boost house prices and encourage

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homeownership. The Obama Administration’s First-Time Home Buyer Tax Credit is one example of such short-term interventions.

In this paper, we study the effect of such policy interventions in the housing market on prices, quantities and welfare in a general equilibrium model with heterogeneous agents. We consider households who differ along immutable characteristics such as age and productivity to ask who would win or lose from a number of government policies. We first focus on the effects of the recently introduced temporary home purchase tax credits. We find that they can support house prices and increase trading volume in the short-run, but have a negative welfare impact on the majority of the population. In addition, after an initial support for prices and volume, both fall below their baseline level after the tax credit is removed.

We also consider the effects of possible permanent changes to a number of current government policies. Here we focus on the tax-deductibility of mortgage interest payments and the tax-exclusion of rents derived from owner-occupied housing. Specifically, we conduct two experiments to analyze policy changes that (i) introduce taxes on imputed rents and (ii) remove all taxes on rental income (both real and imputed), while simultaneously removing any deductions associated with such income. These policy changes would end the unequal tax-treatment of owner-occupied and rental housing. We first analyze the effects of these policies by comparing stationary equilibria under alternative policy regimes. More importantly, however, we extend our analysis to include the transition between relevant stationary equilibria. This allows us to determine the winners and the losers if the U.S. should choose to change the current policy regime. Since the transition to a new steady state often takes a number of decades, analyzing the transition path is very important before any policy recommendations can be made.

When comparing stationary equilibria, we find that removing asymmetries in the treatment of owner-occupied and rental housing in the tax code leads to welfare gains for almost all agents. During the transition to the new steady state, the welfare effects are more varied, though still positive on aggregate. For example, about 82% of agents would be better off in a steady state with neither mortgage interest deduction nor a tax on rental income. This is due to general-equilibrium effects on prices and an increase in lump-sum transfers facilitated by higher government revenues. However, the introduction of the policy change leads to immediate welfare losses for about 25% of households. This is driven by an overshoot of prices, which decline by over 4% in the period after the policy change, before recovering to a level about 2% below the baseline steady state.

When comparing the two permanent changes to the tax code, our results suggest that a removal of the mortgage interest deduction combined with a removal of taxes on rental income would be the preferred way of correcting the asymmetry in the tax-treatment of
owner-occupied and rental housing from an aggregate welfare perspective. Fewer agents lose since house prices fall by less following the policy change. However, the distribution of gains and losses is also different: While the introduction of a tax on imputed rents primarily hurts the richest agents, the removal of mortgage interest deductibility and the tax on rental income largely harms middle-income households.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. The government interventions we consider are described in section 3. Section 4 introduces the model. Section 5 discusses the welfare criterion used for the subsequent analyses. In section 6 the calibration of the baseline economy is described. Section 7 discusses the effects of the First-Time Homebuyer Tax credit, and its subsequent extension to repeat buyers. Sections 8.1 and 8.2 analyze (i) the introduction of taxes on imputed rents and (ii) the removal of taxes on rental income, in addition to a removal of mortgage interest deductibility. We consider prices, quantities and aggregate and distributional welfare effects, both across steady states, and along the transition between steady states. Section 9 concludes.

2 Literature Review

There are a number of recent papers that study the implications of government intervention in the housing market. We expand on this literature by considering the transition between steady states, which we argue are critical for policy analysis, and which have not previously been analyzed. In addition, the effect of temporary home buyer tax credits has not been studied extensively.

The paper by Chambers, Garriga and Schlagenhauf (2006) is probably closest to our approach, particularly in the modeling of the rental market. They study the effect of the asymmetric tax treatment of homeowners and landlords in a general equilibrium overlapping generations model. A revenue neutral reform to remove the asymmetry implies modest welfare gains. The authors also analyze the effects of a permanent housing voucher program to cover part of downpayments for low-income households. They do not contrast different approaches to removing the asymmetry in the tax framework, and do not consider the transition between steady states.

Gervais (2002) examines the preferential tax treatment of housing capital in a dynamic life-cycle economy where housing rental services are provided by a rental firm. His model abstracts from uncertainty, adjustment costs and the collateral role of housing, and focuses on tax wedge that makes owning preferable to renting. He finds that mortgage interest deductions and the taxation of imputed rents have only small distributional effects. Cho and Francis (2008) consider a set-up similar to that of Gervais (2002) and study the effect
of the tax-treatment on wealth inequality. They argue that removing mortgage interest deductibility and taxing imputed rents reduces the Gini coefficient by 0.04. Neither of these two papers considers transitions between steady states.

Jeske and Krueger (2007) build a general equilibrium model with competitive housing and mortgage markets where the government provides banks with insurance against aggregate shocks through its implicit guarantees for Fannie Mae, Freddie Mac and Ginnie Mae. The guarantee generates a mortgage interest subsidy to homeowners which leads to a larger housing stock and higher default rates as mortgage holders increase their leverage. The subsidy benefits mostly high income and high wealth households, and its elimination would lead to an aggregate welfare gain.

The only paper in this literature that we are aware of which considers an explicit transition path between stationary equilibria is by Kiyotaki, Michaelides and Nikolov (2009). The authors study the distributional consequences of aggregate shocks through their effect on house prices. They construct a general equilibrium life-cycle model of a production economy where capital and land are used to build real estate. When the share of land in real estate is large, an exogenous shock to expected productivity or the world interest rate leads to large swings in house prices and a significant redistribution between net buyers and net sellers of houses. Their model does not incorporate the tax treatment of real estate.

3 Government Intervention in the Housing Market

There is a wide-spread belief that homeownership has important personal and societal benefits. On an individual level, homeownership appears to be associated with life satisfaction (Rossi and Weber, 1996). Moreover, there are supposedly large positive externalities from homeownership, as homeowners have an incentive to take care of their property and their local neighborhood (Rohe and Stewart, 1996) Not surprisingly then, government intervention is the housing market is large, and has been primarily directed at increasing homeownership rates. The National Homeownership Strategy (1995) states that “Homeownership is a commitment to strengthening families and good citizenship. Homeownership enables people to have greater control and exercise more responsibility over their living environment.” Below we first describe some recent, temporary government interventions in the housing market, focusing on home buyer tax credits. We then discuss a number of permanent government interventions through the tax code, and consider potential alternatives to the status quo. Here we concentrate on the non-taxation of owner-occupied rents, and the tax-deductibility of mortgage interest payments.
3.1 Home Buyer Tax Credits

As part of the American Recovery and Reinvestment Act of 2009, Congress authorized a first-time home buyer tax credit of up to $8,000 to stimulate the housing market. On November 6, 2009, the tax credit was expanded to include existing homeowners who are purchasing a home to be their principal residence (repeat buyers). They were eligible for a tax credit of up to a maximum of $6,500. Both tax credits expired on April 30, 2010. Section 7 analyzes both of these credits. While our policy analysis focuses on the effects of the federal tax credits, a number of U.S. states have recently introduced their own home buyer tax credit programs.

3.2 Current Tax Policy Regime and Potential Alternatives

Among the most important permanent aspects of the tax code that affect decisions in the housing market are the income-tax exemption of imputed rents from owner-occupied housing and the deductibility of mortgage interest payments from taxable income. In the U.S. a landlord pays taxes on the income received from rental units. At the same time the implicit income from owner-occupied housing is exempt from income taxation. This asymmetry between landlords and owners leads to a bias in favor of owner-occupied housing. Somewhat offsetting this bias, landlords in the U.S. are able to deduct the depreciation of their rental property from the rental income received. In addition, households that itemize deductions in their tax returns can also deduct mortgage interest payments from their tax bill. This is generally considered to be a subsidy that encourages homeownership and leads households (both renters and owners) to over-consume housing services. Glaeser and Shapiro (2003) report that in 1999, $773 billion were deducted by 40 million homeowners, which makes mortgage interest payments the second largest federal deduction after state taxes.

The U.S. policy choices are by no means universal. In 1993, imputed rents were taxed in the 3 years prior to a home purchase. The tax credit phases out for first-time home buyers with a joint adjusted gross income exceeding $150,000. For purchases after November 6, 2009, this limit was increased to $225,000. Partial credits are available for households with an AGI above these limits. The tax credit is also capped at 10% of the house value. The tax credit is refundable. This means that the credit can be claimed even if the taxpayer has little or no federal income tax liability to offset.

On March 25, 2010, California Governor Arnold Schwarzenegger signed a $200 million program into law. This tax credit, which has no income limits for eligibility, is available to any California tax payer. Current homeowners are only eligible if they buy a newly-built, previously unoccupied home. First-time home buyers are eligible when they buy a newly-built or an existing home. The tax credit is worth 5% of the purchase price, up to a limit of $10,000, with the payment spread evenly over three years. This tax credit comes on top of a previous $100 million credit which was rolled out in March 2009 and exhausted by July 2009.

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9 of 24 OECD countries (Gervais, 2002). For example, in the Netherlands owner-occupied homes are considered a source of income. Taxpayers must include an imputed rental income from their owner-occupied homes in their taxable incomes, but can deduct the costs associated with this income source, including mortgage interest payments. The imputed rental income is calculated as 0.6% of the value of the house, up to a maximum of €8,750. Whether mortgage interest payments can be deducted for tax purposes is also not uniform across countries. Mortgage interest payments are not deductible in Germany, France, the UK and Sweden. In some countries, such as Belgium, Italy and Spain, mortgage interest payments are deductible only up to a limit (Hoeck and Radloff, 2007).

In this paper, we consider a number of policy experiments. There are several ways to remove the asymmetric tax treatment of owner-occupied and rental housing. One way would be to introduce income taxation on imputed rents, similarly to the Netherlands, while allowing owner-occupiers to deduct depreciation expenses on top of the mortgage interest payments they can already deduct under the current policy environment. The effects of such a policy are considered in section 8.1. In that case, both owner-occupied housing and rental housing are subject to the same taxes, and allow the same deductions (mortgage interest payments and depreciation). A second way to eliminate the asymmetry in tax-treatment would be to simultaneously remove all taxes on rental income (both real and imputed), as well as any deductions for mortgage interest and depreciation. We consider the impact of such a policy change in section 8.2.4

4 Model

To analyze the distributional effects of government interventions in the housing market, we build a heterogeneous-agent overlapping-generations equilibrium model of the housing and rental market. Households derive utility both from housing services and from a nondurable numeraire consumption good. To obtain housing services, households decide whether to live in owner-occupied housing or in rental housing. In addition, homeowners can purchase additional housing stock and lease those units to other households. The model allows for a flexible set of non-convex housing transaction costs. Aggregate housing supply responds to changes in prices. Aggregation of individual household decisions yields demand for owner-occupied housing and the supply and demand for rental units. Household decisions are affected by government interventions through the tax code. House prices $p$ and rents $p^r$

4 A third way to end the asymmetric tax treatment of owner-occupied and rental housing would be to remove taxes on rental units, while keeping in place the deductibility of mortgage interest payments. This would set their tax-treatment equal to the current treatment of owner-occupied housing in the U.S. In this paper, we do not consider this experiment.
adjust to clear both the housing and the rental market.

4.1 Setup of the Household Problem

Preferences: Agents receive utility from consuming housing services $\tilde{h}$ and the nondurable numeraire consumption good $c$. Preferences over consumption and housing services are non-separable. Everything else equal, agents prefer owner-occupied housing to rental housing. In terms of the model, agents weight housing services with a factor $\lambda$ in their utility function. $\lambda \leq 1$ takes a value of one for owner occupied housing and a value less than one for rental housing.\(^5\) The agents’ period utility function is:

$$u(c, \tilde{h}) = \left( c^\alpha + \omega(\lambda \tilde{h})^\alpha \right)^{\frac{1-\rho}{\alpha}}$$  \hspace{1cm} (1)

Note that $\alpha$ parameterizes the degree of complimentarity between housing and consumption while $\rho$ is the coefficient of relative risk aversion.

Housing Services: To receive housing services, agents can either purchase housing ($h > 0$) or rent housing units ($h^r > 0$). Homeowners have the additional option to supply units to the rental market ($h^r < 0$). The maximum amount of housing leased to other households is limited by the agent’s owned housing stock. The amount of housing services $\tilde{h}$ that an agent consumes is then given by:

$$\tilde{h} = \begin{cases} 
  h^r & \text{if Renter} \ (h^r > 0) \\
  h + h^r & \text{if Owner} \ (h^r \leq 0).
\end{cases}$$  \hspace{1cm} (2)

In addition, we introduce a minimum size for owned housing. A similar feature appears in Cocco (2005), Gervais (2002) and many other papers in this literature.

$$h \geq h_{\text{min}}$$  \hspace{1cm} (3)

This set-up allows us to distinguish the consumption aspect of housing from the investment aspect of housing. It assumes that a household can only live in one place at a time, and will therefore either derive utility from the amount of rented housing or from the amount of owned housing that is not leased to other people. Households cannot augment their housing

\(^5\)There is significant evidence for this in the empirical literature, e.g. Galster (1987). From an aggregate welfare perspectives, $\lambda$ can also capture some of the supposed societal benefits associated with homeownership discussed in section 3.2. Everything else equal, and economy where all agents are owner-occupiers has more aggregate welfare than an economy with only renters.
consumption by renting additional units on top of their owner-occupied home.\footnote{One assumption here is that housing is divisible for \( h > h_{\text{min}} \). Alternative modeling assumptions would require us to have a number of different types of housing (small, medium, big), with state variables for each, and market clearing for each in the rental and the purchase market. While this would potentially generate some additional predictions for different segments of the housing market, it would complicate the computational approach significantly, without adding additional insights for the questions we consider.}

**Demographics and Endowment:** Agents work for \( J - 1 \) periods before they retire. In our simulations we set the period length to be five years and \( J \) to 10. This generates 9 working cohorts aged between 20–25 and 60–65. Once retired, agents face a constant mortality rate \( \kappa \). An agent who dies unexpectedly sells the house on the market, services potential outstanding debt and consumes the proceeds before exiting the model.\footnote{This formulation of the life-cycle allows to abstract from inter-generational linkages through the bequest motive. Alternatively, one could specify an exogenous age \( T \) at which agents exit the model and leave their remaining financial and housing wealth to their descendants.} In every period, a new cohort of young agents enters the economy and replaces the dying retirees such that the overall mass of agents remains constant. Working agents are endowed with one unit of labor, which they supply inelastically. Agents have age-specific productivity \( \gamma_j \), and face persistent idiosyncratic shocks to their labor productivity \( \eta_{i,t} \). Labor income \( y_{i,j,t} \) can be expressed as:

\[
y_{i,j,t} = \gamma_j \eta_{i,t} \tag{4}
\]

where \( \eta_{i,t} \) is assumed to follow an AR(1) process in log terms with \( |\phi| < 1 \) and \( \varepsilon_{i,t} \sim N(0, \sigma_y^2) : \)

\[
\log \eta_{i,t} = \phi \log \eta_{i,t-1} + \varepsilon_{i,t} \tag{5}
\]

The stationary distribution of agents over age \( j \) and the productivity variable indexed by \( i \) is given as \( \mu(i,j) \). Retirees receive Social Security benefits as a given fraction \( g \) of the working population’s average income. Benefits are thus set at:

\[
\check{y} = g \sum_{j=1}^{J-1} \int_i y_{i,j} \mu(i,j) di \tag{6}
\]

This social security payment is financed by a tax \( \tau_{ss} \) on labor income. We assume that the Social Security agency breaks even in every period and adjust the tax rate accordingly.

**Depreciation, Transaction Costs and Moving Shock:** An agent’s housing stock depreciates at rate \( \delta \) each period. The process of buying and selling houses involves significant costs. These include the time cost of searching for a suitable home and broker fees. In our model, an agent who buys a house incurs a cost as a fraction \( \phi^b \) of the value of the new house, \( ph \). Similarly, an agent who sells her home incurs a cost as a fraction \( \phi^s \) of the value of
the house she is selling, $ph_{-1}(1-\delta)$. Transaction costs are treated as dead-weight loss for the economy. At the beginning of every period some fraction of working-age households receive an exogenous moving shock, $z = 1$. This moving shock captures job-related relocations. Households receiving a moving shock need to sell their current house and pay transaction costs. We set $z = 0$ for all retirees. The resulting formulation of transaction costs is:

$$AC(h_{-1}, h, z) = \begin{cases} 
0 & \text{if } z = 0 \land (h = (1-\delta)h_{-1} \text{ or } h = h_{-1}) \\
p(\phi^bh + \phi^s_{-1}(1-\delta)) & \text{otherwise} 
\end{cases}$$  (7)

A household that has not received a moving shock has three options: It can maintain its housing stock at last period’s level. This costs maintenance expenses $p\delta h_{-1}$. It can also let the housing stock depreciate. Both these options do not involve transaction costs. If the household chooses a different level of housing stock, transaction costs need to be paid.$^8$

The cost of moving between rental units is smaller. Most households that rent do not engage in expensive remodeling work and brokerage fees are – if applicable at all – much lower. In our model we normalize moving costs for renters to zero. This allows a substantial numerical simplification, which is discussed in appendix A.1. The decision to become a landlord, on the other hand, involves non-trivial costs. Owners of rental units need to search for and screen potential renters, conduct administrative work and carry the risk of unfilled inventory. We model this as a fixed per period participation cost $\xi$.

Our formulation of $AC$ suggests that the transaction costs for buying and selling rental units are equal to the transaction costs for buying and selling owner-occupied units. It also assumes that housing units can be transformed costlessly between rental units and units for owner-occupation. This removes the need for an additional state variable to capture the amount of rental housing owned by landlords. A popular alternative for modeling rental supply in the literature is to assume that rental units are supplied by a two-period rental firm (see Gervais, 2002; Cho and Francis, 2008). In the first period, this firm takes deposits from households (alternatively, households purchase risk-free equity in the rental firm). It uses the proceeds to buy rental units which are supplied to the market. In the second period, the firm pays interest on deposits, and sells the non-depreciated stock of housing to a new rental firm. In steady-state this rental firm makes zero profit, allowing to abstract from ownership of the firm. This way of modeling rental supply makes the (often implicit) assumption that transaction costs for rental units are zero. In steady-state without aggregate risk, the introduction of transaction costs for a rental firm would not matter, since the total rental

$^8$We do not allow households to engage in partial transaction-cost free maintenance. This is to facilitate the computational solution of this problem on a $\delta$-spaced grid (see the computational appendix B).
stock is constant. However, modeling rental firms becomes more involved when prices change unexpectedly following a policy change. This is relevant for the analysis of temporary tax credits and the transitions between steady states. In particular, following a drop in prices and rents, the firm loses in value (either the equity drops in value, or depositors cannot be repaid). This is a first-order welfare effect of a policy change. To capture this effect, ownership of the rental firm would have to be tracked to determine which agents bear the loss. This would require an additional state variable. For these reasons, we consider our formulation of rental supply advantageous in an economy where we want to track welfare away from steady states for experiments that generate unexpected price changes.\(^9\)

**Borrowing and Saving:** Households have access to a risk free bond \(s'\) that pays interest \(r\). The choice of \(s'\) can either be positive, in which case the agents saves, or negative, in which case the agent borrows. Markets are incomplete in the sense that agents can only borrow against the value of their house. Their ability to hold debt is restricted by a downpayment requirement, \(d\).

\[
s' > -(1 - d)hp. \tag{8}\]

When borrowing, agents pay a higher interest rate \(r + m\). The mortgage premium \(m\) captures the probability of mortgage default in reduced form.\(^10\) Therefore, the pre-tax return on asset position \(s\) is given by \((1 + r + mI_{s<0})\), where \(mI_{s<0}\) captures the fact that the interest rate paid by an agent on a mortgage \((s < 0)\) gets adjusted upwards by the mortgage premium \(m\). For an arbitrary policy regime, the budget constraint of a working agent can be expressed as:

\[
c + s' + ph + AC + \max\{0, T - D\} = p'(h - \tilde{h}) + (1 + r + mI_{s<0})s + (1 - \tau^{ss})y + p(1 - \delta)h_{-1} + Tr \tag{9}\]

\(T\) denotes the tax burden, and comprises taxes on labor income, capital income and rental income. The sum of applicable tax deductions is denoted by \(D\) and is capped at the level of the total tax owed. \(Tr\) represents a lump-sum transfer from the government to all agents – this transfer adjusts to ensure that the government breaks even every period. The government intervenes through the exact specification of \(T\) and \(D\). The modelling of the policy

\(^9\)In addition, the "buy-to-let" strategy that we consider in our model seems to be the rule rather than the exception, as rental units in the U.S. are predominantly supplied by private investors. Chambers, Garriga and Schlagenhauf (2006) cite evidence from the Census Bureau’s 1996 Property Owners and Managers Survey (POMS). The authors report that 86.3% of all rental units are owned by individual investors.

\(^{10}\)Note that there is no explicit mortgage default in our model. In a related paper, Jeske and Krueger (2007) include stochastic housing depreciation rates which implies that an unexpectedly high depreciation shock can lead homeowners to default on their mortgage.
alternatives considered in this paper will be presented in detail in section 4.3.

**Recursive Formulation of Household Problem:** The problem of the retiree can be expressed in recursive form as:

\[
V^J(h_{-1}, s, z; p^r, p, p_{-1}, Tr) = \max_{s, h, h} \left\{ u(c, h) + (1 - \kappa) \beta E V^J(h, s', z'; p'^r, p', p, Tr') + \kappa (u(c + \varphi, h) - u(c, h)) \right\}
\]

subject to:
\[
c + s' + ph + AC + \max\{0, T - D\} = p^r(h - h) + (1 + r + mI_{s<0}) s + \hat{y} + p(1 - \delta)h_{-1} + Tr
\]
\[
\varphi = s'(1 + r + mI_{s<0}) + (1 - \phi^{sell})(1 - \delta)p'h'
\]
\[
p'^r = \Gamma_1(\Omega_t, \ldots), p' = \Gamma_2(\Omega_t, \ldots), Tr' = \Gamma_3(\Omega_t, \ldots)
\]

In this formulation, \(\varphi\) captures the additional resources that the agent consumes in the period before his death. It is equal to the sum of the resources obtained from selling a house and the financial assets of the agent. For the remaining cohorts 1 to \(J - 1\), the problem can be solved backwards. The problem of working cohort \(j\) can be expressed as:

\[
V^j(h_{-1}, s, y, z; p^r, p, p_{-1}, Tr) = \max_{s, h, h} \left\{ u(c, h) + (1 - \kappa) \beta E V^{j+1}(h, s', y', z'; p'^r, p', p, Tr') \right\}
\]

subject to:
\[
c + s' + ph + AC + \max\{0, T - D\} = p^r(h - h) + (1 + r + mI_{s<0}) s + \tau^{ss}y + p(1 - \delta)h_{-1} + Tr
\]
\[
p'^r = \Gamma_1(\Omega_t, \ldots), p' = \Gamma_2(\Omega_t, \ldots), Tr' = \Gamma_3(\Omega_t, \ldots)
\]

\[
(1), (2), (3), (4), (5), (7), (8)
\]

**Expectation Formation:** In these recursive specifications, \(\Gamma_1, \Gamma_2\) and \(\Gamma_3\) refer to the laws of motion for prices and transfers that households assume. In our model, \(Tr, p\) and \(p^r\) are the key aggregate state variables relevant for the household problem. Households form expectation about future prices which – in addition to being a function of current prices and aggregate variables like the size of the existing housing stock – could in principle depend on the full distribution of agents over the state space, \(\Omega_t\), a large and intractable object. We assume that agents form expectations rationally. Given the absence of any aggregate uncertainty, this means that agents have perfect foresight about the future path of prices, except in periods with unexpected policy changes.

In a stationary equilibrium, prices and transfers are constant. Agents’ price forecasts are thus very simple: \(p'^r = \Gamma_1(p^r) = p^r, p' = \Gamma_2(p) = p\) and \(Tr' = \Gamma_3(Tr) = Tr\). Along
the transition path between steady states, prices and transfers are no longer constant. In
the absence of aggregate uncertainty, the assumption of rational expectations implies that
following an unexpected change in policy (such as the temporary introduction of home buyer
tax credits), the households have perfect foresight about the time-path of prices and transfers
on the transition to the eventual steady state. To calculate the transition, we adopt a method
pioneered by Auerbach and Kotlikoff (1987). It assumes that the economy converges to its
new steady state within a given number of periods. Agents have perfect foresight and
know the sequence of prices during the transition path. Given price expectations, market
clearing is checked to ensure that actual prices given the expectations are consistent with
the expectations. Appendix B describes the solution algorithm.

4.2 Housing Supply

There is a competitive construction sector that transforms land available for development
\( L \) into new housing stock \( H^{\text{new}} \). This sector purchases land at a constant price that we
normalize to 1 and immediately sells the housing stock in the market at price \( p \). Following
Davis and Heathcote (2005) we assume that every period some amount of land of fixed
quality is made available for development. Not all of this land was formerly unoccupied,
since the depreciation process frees up previously occupied land for development. Every
period, as more of the available land is developed, developing additional units becomes more
expensive. Alternatively, every period the available land is developed in decreasing order of
quality. This generates decreasing returns in the production of new housing stock.

\[
H^{\text{new}} = \psi_1 L^{\psi_2}
\]

where \( \psi_2 \leq 1 \). The construction firm thus solves the following static problem:

\[
\max_L \left\{ p \psi_1 L^{\psi_2} - L \right\}
\]

The resulting law of motion for the aggregate housing stock is:

\[
H = H^{-1}(1 - \delta) + H^{\text{new}} = H^{-1}(1 - \delta) + \psi_1 \left( \frac{1}{p \psi_1 \psi_2} \right)^{\left( \frac{\psi_2}{\psi_2 - 1} \right)}
\]

This implies that at higher prices more resources are invested into housing construction.
Equivalently one can say that with higher prices progressively worse quality land is developed.
We assume that the construction sector in our small open economy is owned from abroad.\textsuperscript{11}

### 4.3 Government Intervention in the Model

We consider an environment where the government can tax labor income, capital income and rental income. In our formulation, taxes can be levied both on actual rental income as well as on imputed rental income from owner-occupied housing. In the benchmark calibration, taxes on imputed rents are deducted to make the model consistent with current U.S. policy.

A policy regime is determined by the specification of each agent’s tax bill, \( \max\{0, T-D\} \), which is a function of total tax owed \( T \) and potential deductions \( D \). The total tax burden can be broken down as follows:

\[
T = \sum \begin{pmatrix}
\tau_y y \\
\tau^s r s I_{\{s>0\}} \\
\tau^r (p^r - \delta p)h
\end{pmatrix}
\]

- labor income taxes
- capital income tax
- tax on rental income (real and imputed) less depreciation

The tax-base for income on rents (real and imputed) gets adjusted by the value of the depreciation of that property, reflecting current U.S. policy. The deductions that are considered in this paper are summarized below, where the indicators \( \Psi_1 \) to \( \Psi_4 \) are used as a convenient way to combine policy alternatives in a single equation:

\[
D = \sum \begin{pmatrix}
\Psi_1 \cdot \tau^r \cdot \hat{h}(p^r - \delta p) I_{\{h>0\}} \\
\Psi_2 \cdot \tau^y \cdot (-1)(r + m)s I_{\{s<0\}} \\
\Psi_3 \cdot TC^{FTHB} \cdot I_{\{h>0 \land h-1=0\}} \\
\Psi_3 \cdot TC^{GHB} \cdot I_{\{h>0 \land h \neq (1-\delta)h-1 \land h \neq h-1\}}
\end{pmatrix}
\]

- No tax on owner-consumed housing
- Deductibility of all mortgage interest
- First-Time Home Buyer tax credit
- General Home Buyer tax credit

In the baseline policy regime, which corresponds to the current U.S. tax policy, we set \( \Psi_1 = 1, \Psi_2 = 1, \Psi_3 = 0 \) and \( \Psi_4 = 0 \). In section 7.1 we analyze prices, quantities and welfare after setting \( \Psi_3 = 1 \) for one period. In section 7.2, we set \( \Psi_4 = 1 \) for one period. In section 8.1 we analyze the effects of a permanent introduction of taxes on imputed rents, and thus set \( \Psi_1 = 0 \). In section 8.2 we set \( \tau^r = 0 \), and \( \Psi_2 = 0 \), removing any taxes on rental income as well as any deductions.

In our welfare comparisons, it will be important to consider the tax revenue implications of potential policy alternatives. We require the government to run a balanced budget in

\textsuperscript{11}If the housing sector were owned by the households in our model, the distribution of ownership would need to be tracked, at the expense of another state variable. This would be particularly important along the transition path, since construction sector profits will change. A computationally simpler alternative would assume that the construction sector is owned in equal shares by the population, or, equivalently, owned by the government, which distributes any profits lump-sum.
every period, that is:

\[
\int \int \int \int_{i,j,h,s} \max\{0, T(i,j,h,s) - D(i,j,h,s)\} \mu(i,j,h,s) di dj dh ds = Tr \quad (16)
\]

This balanced budget constraint makes the agent’s tax bill and the lump sum government transfers important redistributive channels. For example, a reform that increases tax revenues by abolishing deductions can benefit low-income households through higher government transfers.\(^\text{12}\)

### 4.4 Market Clearing and Equilibrium Definition

Purchase and rent prices for housing are determined every period by a market-clearing condition in both markets. As illustrated above, the supply of rental units is endogenous as rental units are supplied by households who decide to become landlords. The market clearing conditions are formally expressed as follows:

\[
\int \int \int \int_{i,j,h,s} h(i,j,h,s) \mu(i,j,h,s) di dj dh ds = H \quad (17)
\]

\[
\int \int \int \int_{i,j,h,s} h^r(i,j,h,s) \mu(i,j,h,s) di dj dh ds = 0 \quad (18)
\]

We can now formally define a stationary recursive competitive equilibrium for our economy.

**Definition 1** Given an institutional setup \(T\) and \(D\) that includes a set of government policies \(\tau_y\), \(\tau_s\) and \(\tau_r\), and an interest rate \(r\), a **stationary recursive competitive equilibrium** is defined by prices \(p\) and \(p^r\), value and policy functions for households \(V\), \(c\), \(h\), \(h^r\), \(s'\), a policy for the construction sector \(H^{new}\), a lump sum government transfer \(Tr\) and an invariable distribution of households \(\mu\) (over \(i, j, h, s\)) such that

1. Given prices and transfers, households optimize,

2. Given prices, the construction sector optimizes,

3. The housing and rental markets clear,

4. The government budget breaks even in every period,

5. The distribution \(\mu\) is invariant with respect to the exogenous Markov process for labor productivity and the policy functions \(h\) and \(s'\).

\(^{12}\)One could also choose to clear the government budget by adjusting the income tax rate – here the adjustment would impact high productivity households more. A robustness check has shown that this does not change any of the main results of this paper.
5 Welfare Criterion for Policy Analysis

We are interested not only in the price and quantity effects of government interventions, but also in their aggregate and distributional welfare effects. We first describe how we analyze instantaneous welfare effects. This is used to measure the effects of a temporary policy, in this case the home buyer tax credits. This measure will also be employed to determine the immediate welfare effects following a permanent change in policy. We then discuss the criterion used to compare welfare across steady states.

Welfare analysis that is conducted by comparing stationary equilibria is useful for two purposes. First, it can be used as a comparison between the status quo and the policy regime of another country. Second, it can be seen as an evaluation of long-run effects. However, this approach is less suited to describe the potential welfare consequences for a specific group of people that would result from a change in policy. By considering the immediate welfare impact following changes in the policy regime, we also provide this type of comparison, which is relevant for policy-makers.

**Instantaneous Welfare Effects:** We are interested in measuring the immediate change in expected discounted life-time utility following a reform. Expected discounted utility is equivalent to the value functions $V$ in (10) and (11). To help with the interpretation of welfare changes, we present them in consumption equivalent units. Consider two economies that are in the baseline steady state in period $t - 1$. At the beginning of period $t$ the first economy unexpectedly introduces a policy reform (either a temporary tax credit, or a permanent reform), while the second economy does not. Let $\hat{V}_t^j$ represent the value function for an agent of age $j$ in period $t$ in the first economy (the one introducing the change), while $V_t^j$ represents the value function in the second economy. Also let $c^*$ and $\bar{h}^*$ be the solution to (10) or (11) in the baseline steady state. That means, for all $j$ we have

$$V_t^j = u(c_t^*, \bar{h}_t^*) + \beta E[V_{t+1}^{j+1}].$$

For a given set of state variables $(h, s, y, j)$, the consumption equivalent change is given by $\Delta c$, which can be found by inverting the following equation:

$$\hat{V}_t^j = u\left((c_t^* + \Delta c), \bar{h}_t^*\right) + \beta E[V_{t+1}^{j+1}].$$

Under this formulation, $\Delta c$ has an intuitive interpretation. It measures the one-time change to period $t$ consumption (which we report as a fraction of average period labor income $\bar{y}$) of agents in the second economy (the one without a policy change) required to ensure they are as well off as agents of the same type in the first economy. A positive value for $\Delta c$ suggests that agents are better off immediately following the introduction of the policy change. It is important to note that the consumption transfer is made after the agents have optimized (without suspecting either a change in policy, or the potential for a consumption
transfer). That is, we do not allow the agents to re-optimize their behavior in period \( t \).

**Steady State Comparison:** For permanent policy changes, we also compare welfare between alternative steady states. We assess each household’s welfare in the baseline case, \( V \), and in the new stationary equilibrium following the policy change, \( \hat{V} \). Again we consider the change in one-period contemporaneous consumption \( \Delta c \) that would make a specific agent in the baseline steady state as well off as an agent with the same vector of state variables in the alternative steady state. As before, this can be determined by inverting equation (19).

One way to interpret this consumption equivalent variation is the following. Consider two countries with an economy in steady state, one with the baseline U.S. policy regime and another with the experiment calibration. Assume that the welfare of a certain type of household is higher in the post-reform steady state than in the status quo (where type is defined by a combination of \( h \), \( s \), age and productivity). In that case, the \( \Delta c \) represents the one-time increase in consumption that this household type in the status quo would need to be offered to reject a switch of positions with a similar household in the new steady state. Equivalently, if the reform has a negative welfare impact, the consumption equivalent (\( \Delta c < 0 \)) is the one-time reduction in consumption that households would be happy to accept to not have to switch with a similar households in the new, lower-welfare steady state.

6 Calibration

In this section we describe the calibration of parameters used in the baseline model. Some parameters, such as preference and income process parameters, are taken from the literature where they have been previously estimated. Other parameters are calibrated so that the baseline steady state approximates important and relevant moments from the U.S. economy.

\footnote{We considered a number of alternative measures of changes in welfare. One measure could be to consider the change in the agent’s wealth required to make them indifferent between the two steady states. That is, we could determine the amount \( \bar{s} \) such that \( V(s + \bar{s}, h, y, j) = \hat{V}(s, h, y, j) \). This would implicitly allow the household to allocate the additional resources optimally between consumption \( c \), housing \( h \) and savings \( s' \), rather than requiring it to consume all the compensating resources immediately. However, in a model with borrowing constraints where \( s \) is bounded from below, this is difficult, since a compensating change could violate constraint (8). This is likely to be a problem for agents with a full mortgage (of which there are a non-trivial amount in our model). Furthermore, this would take us off our grid for voluntary savings \( b \) (see Appendix A.3). Therefore, quantifying welfare effects by considering changes in wealth is suboptimal in our model. We also considered a welfare change that would add to the household’s consumption over a number of periods (potentially in every future period). However, in this case the assumption that households do not anticipate these transfers is more problematic.}
6.1 Calibration of Pre-Defined Parameter Values

Table 1 summarizes the set of pre-defined parameters that we take as given in our model. We use parameters that are approximately in the center of the range of values used in the literature. Recall that a period in the model refers to a five year time span. To ease comparison with the literature we discuss the calibration in terms of annual values.

Table 1: Pre-Defined Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Model Value</th>
<th>Annual Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$ Risk-free interest rate</td>
<td>0.127</td>
<td>0.024</td>
</tr>
<tr>
<td>$m$ Mortgage premium</td>
<td>0.088</td>
<td>0.040</td>
</tr>
<tr>
<td>$\nu$ Elasticity of substitution between $c$ and $\hat{h}$</td>
<td>1.28</td>
<td>–</td>
</tr>
<tr>
<td>$\rho$ Coefficient of relative risk aversion</td>
<td>2.0</td>
<td>–</td>
</tr>
<tr>
<td>$1 - \kappa$ Conditional survival probability of retirees</td>
<td>0.73</td>
<td>0.939</td>
</tr>
<tr>
<td>$g$ Replacement ratio</td>
<td>0.386</td>
<td>–</td>
</tr>
<tr>
<td>$\tau^y$ Tax rate on labor income</td>
<td>0.275</td>
<td>–</td>
</tr>
<tr>
<td>$\tau^r$ Tax rate on rental income</td>
<td>0.275</td>
<td>–</td>
</tr>
<tr>
<td>$\tau^s$ Tax rate on capital income</td>
<td>0.292</td>
<td>–</td>
</tr>
<tr>
<td>$\phi^b$ Transaction costs for buyer (fraction of house value)</td>
<td>0.025</td>
<td>–</td>
</tr>
<tr>
<td>$\phi^s$ Transaction costs for seller (fraction of house value)</td>
<td>0.06</td>
<td>–</td>
</tr>
<tr>
<td>$\delta$ Housing stock depreciation rate</td>
<td>0.096</td>
<td>0.020</td>
</tr>
<tr>
<td>$\phi$ Persistence of income process</td>
<td>0.85</td>
<td>–</td>
</tr>
<tr>
<td>$\sigma^2_y$ Variance of income innovations</td>
<td>0.30</td>
<td>–</td>
</tr>
<tr>
<td>$d$ Downpayment requirement</td>
<td>0.20</td>
<td>–</td>
</tr>
<tr>
<td>$\epsilon$ Price Elasticity of Housing Construction</td>
<td>2.5</td>
<td>–</td>
</tr>
</tbody>
</table>

Note: The third column lists the parameter value used in the model simulations. The fourth column shows the corresponding annual value if appropriate.

Interest Rate and Mortgage Premium: We consider a small open economy model. The interest rate paid on the risk-free bond is fixed at the average of the 5-year constant-maturity Treasury rate over the period 1995 - 2005, 4.95%, minus the average CPI inflation rate, 2.53%. This is equal to an annual real rate of 2.42%. When borrowing funds to buy a home, households pay a mortgage premium $m$ on top of the interest rate $r$. Freddie Mac's Primary Mortgage Market Survey (PMMS) collects average annual total interest rates for 15-year fixed rate mortgages. The average nominal value between 1995 and 2005 was 6.51%, giving a real value of 3.98%. The model value for $m$ is calculated as $1.0398^5 - 1.0242^5 = 0.088$.

Preferences: The coefficient of relative risk aversion $\rho$ is set to 2, which is a standard value in macroeconomics. For instance, Attanasio and Browning (1995) report estimates for the intertemporal elasticity of substitution between 0.48 and 0.67. The other important coefficient in the period utility function (1) is $\nu = \frac{1}{1-\alpha}$, where $\epsilon$ refers to the intra-temporal elasticity of substitution between nondurable consumption and housing services. Our choice for $\epsilon$ of 1.28 lies between the estimates of Schneider, Piazzesi and Tuzel (2006) who report
a value of 1.24 and the structural estimate of Bajari et al. (2007), which yields a value of 1.32. It also lies in the 95% interval found by Ogaki and Reinhart (1998).

**Demographics:** We use the U.S. Decennial Life Tables for 1989-1991 to calibrate mortality rates for retirees. We calibrate $1 - \kappa$ as the conditional probability of a person aged 65 or above to survive the subsequent five years. This probability is around 73%. Each period, the measure of newly born agents is equal to the measure of those who die and exit the model. As a result, the total population remains constant.

**Taxes and Benefits:** After mandatory retirement at age 65, agents receive a pension financed by a levy on labor income. Following Queisser and Whitehouse (2005) we set the replacement rate to 38.6% of economy-wide average earnings. In calibrating average income tax rates, we follow Diaz and Luengo-Prado (2008). In one of their specifications, they use the U.S. Federal and State Average Marginal Income Tax Rates in the NBER TAXSIM model to construct average tax rates on capital and labor income. They find an average effective tax rate on capital income for the period 1996-2006 of 29.2%. The average effective tax rate on labor income for the same period is 27.5%. Rental income in the U.S. is included in the gross income on which the income tax rate is levied. We thus set $\tau^r = \tau^y$.

**Adjustment Costs in the Housing Market:** Smith, Rosen and Fallis (1988) estimate the transaction costs of changing owner-occupied housing to be approximately $8 - 10\%$ of the value of the unit. This includes search and legal costs, costs of remodeling the unit and psychological costs from the disruption of social life. Yang (2005) assumes transaction costs from a sale to be 6% of the value of the unit sold, and transaction costs from a purchase to be 2% of the value of the unit bought. Iacoviello and Pavan (2009) assume adjustment costs of 4% of value for both the purchasing and the selling party. To keep within these values, we assume costs of 6% of house value for sellers and costs of 2.5% for buyers.

**Depreciation of the Housing Stock:** Leigh (1980) estimates the annual depreciation rate of housing units in the U.S. to be between 0.36% and 1.36%. Cocco (2005) chooses a depreciation rate equal to 1% on an annual basis. Harding, Rosenthal and Sirmans (2007) use data from the American Housing Survey and a repeat sales model to estimate that between 1983 and 2001 housing depreciated at roughly 2.5% per year gross of maintenance, while the net of maintenance depreciation rate was approximately 2% per year. Consistent with these estimates we assume that the housing stock depreciates at an annual rate of 2%.

**Income Process:** Households supply one unit of labor inelastically. However, productivity varies both across age groups and across agents. Household wage income thus depends on two factors, the age-specific factor $\gamma_j$, and the stochastic, individual-specific factor $\eta_{i,t}$. The factor $\gamma_j$ captures the hump-shape of individual earnings profiles over the life-cycle. The age-profile of labor efficiency units is taken from Table PINC-4 of the March Supplement of
the 2000 CPS. To parameterize the process for $\eta_{i,t}$, we build on empirical work by Altonji and Villanueva (2003), who use PSID data to estimate the idiosyncratic component of income as an AR(1) process. Aggregating the data to five year intervals, they report an autoregressive parameter $\phi$ of 0.85 and a variance of innovations $\sigma^2_y$ of 0.3. We discretize this process to an 8-state Markov chain using the procedure of Tauchen and Hussey (1991).

**Downpayment Requirement:** We set the downpayment requirement to 20% of the house value. This choice is consistent with much of the related literature, such as Diaz and Luengo-Prado (2007) and Yang (2005).

**Housing Supply Elasticity:** As discussed above, parameterizing the housing production function is difficult. Empirical estimates of the price elasticity of housing supply vary widely. Blackley (1999) analyzes the real value of U.S. private residential construction put in place. She finds elasticities ranging from 0.8 to 3.7, depending on the dynamic specification of her model. Mayer and Somerville (2000) estimate a flow elasticity of 6, suggesting that a 10% increase in house prices will lead to a 60% increase in housing starts. Furthermore, price elasticities of housing supply vary widely within the United States. As argued by Glaeser, Gyourko, and Saks (2005), supply side regulation (and thus the price elasticity of housing starts) differs by region and city. Some authors, such as Ortalo-Magne and Rady (2006) have hence chosen to fix the housing supply in their model. We take a different approach: In our baseline estimates, we parameterize the housing production function to fit a price elasticity of housing starts of $\epsilon = 2.5$, which is roughly in the middle of the estimated values. We compare these result to model predictions obtained when assuming $\epsilon = 6$, and in a scenario where we assume a constant housing stock, or a zero price elasticity of housing supply. This approach provides bounds on the impact of policy changes.

### 6.2 Calibration Using Method of Moments Approach

In this section we calibrate the remaining model parameters by matching important moments of the U.S. economy. Table 2 summarizes the parameters and the moments we target.

Absolute housing quantities in this model are not easily related to real-world counterparts. This is since one of the parameters $\omega$, $h_{min}$ and $H^{SS}$ can be normalized in the baseline steady state. We set the value of steady-state housing stock in the economy, $H^{SS}$, equal to 1.

**Housing Share in Consumption:** To calibrate the weight of housing in the utility function, $\omega$, we target the share of housing in total household expenditure. Jeske and Krueger (2007) analyze NIPA data and report a value of 14.1% that has been nearly constant over the last 40 years. This corresponds to a value of $\omega$ of 0.149 in the model, which generates a housing share in consumption of exactly 14.1%.
Relative Size of Rental Housing: To calibrate $h_{\text{min}}$, the level of the smallest unit of housing available for purchase, we target the relative size of owner-occupied and rental housing. Using data from the 1999 American Housing Survey, we find that the average size of owner-occupied housing is about 1,860 square feet, while the average size of renter-occupied housing is 668 square feet. When we set $h_{\text{min}}$ to 0.935, our model produces a ratio of the average size of owner-occupied to rental housing of 2.72, very similar to the ratio of 2.78 found in the data. The downpayment for a house of size $h_{\text{min}}$ in the baseline steady state costs about 41% of average annual income.

Homeownership Rate: From the U.S. Census Bureau’s Statistical Abstract of the United States, Table 957, we find that the aggregate homeownership rate in 2000 was about 67.4%. We match this aggregate rate by setting the value of the utility discount for rental units, $\lambda$, equal to 0.887. This value implies that households are indifferent between renting 1,000 square feet of housing and owner-occupying 887 square feet. Figure 1 shows that this calibration does not only reproduce the average U.S. homeownership rate, but also generates a realistic life-cycle profile of homeownership.

Percentage of Landlords: We calibrate the fixed cost of becoming a landlord, $\xi$, to match the proportion of U.S. households that are landlords. Chambers, Garriga and Schlagenhauf (2006) use the American Housing Survey to determine that about 15% of American households are landlords. A value of 0.005 for $\xi$, corresponding to about 1.6% of mean annual income achieves a landlord rate of 14.9%. In the U.S. Census Bureau’s 2004 Economic Survey, annual mean U.S. households income was $60,528, so $\xi$ represents an annual cost of being a landlord of approximately $950.

Loan-to-Value Ratio: We calibrate the time discount rate $\beta$ to match the aggregate loan-to-value (LTV) ratio in the economy. We find that the mean of the 1998 and 2004 Survey of Consumer Finances economy-wide LTV ratios was about 36.3%. When we set the annual discount factor $\beta$ equal to 0.966, the baseline steady state generates an LTV of 36.8%. The model also captures the declining loan-to-value ratios over the life-cycle.
Figure 1: Homeownership Rate for Different Age Groups

Note: Data for the Homeownership Rate by Age comes from the U.S. Statistical Abstract for 2005, Table 957. We take the average for the period 1995 - 2005.

Moving Owners: We calibrate the probability of a moving shock to match the probability of homeowners to move. Cocco (2004) analyzes PSID data and finds a moving probability for homeowners of 24.4% per 5-year period. When we set the exogenous probability of a moving shock to 0.105, exactly 24.4% of homeowners in our model move every period.

7 Tax Credits for Home Buyers

Our model allows us to analyze the aggregate and distributional effects of an unexpected introduction of tax credits for home purchases, starting from the steady state calibrated for the U.S. economy. We assume that the tax credit lasts for one model-period only. In the period when the credit is introduced, agents perceive a price-path for future periods, which converges back to the initial steady state equilibrium. They adjust behavior on the basis of these expectations. Market clearing prices and rents are determined by aggregating individual behavior, given the expectation over the future price path. As discussed in section 4.1, given the rational expectations assumption and the absence of aggregate uncertainty, agents have perfect foresight over the price path back to the initial steady state. We separately analyze the effects of the tax credits extended to first-time home buyers and those extended to all home buyers, including repeat home buyers.
7.1 First-Time Home Buyer Tax Credit

We first consider the effects of a temporary, one-period tax credit for first-time home buyers. We consider a tax credit of $8,000, corresponding the size of the actual U.S. credit discussed in section 3.1. We set $TC^{FTHB}$ such that the tax credit represents the appropriate share of mean income. As discussed in section 6.1, we calculate the price and quantity changes for a number of different assumptions for $\epsilon$, the price-elasticity of housing supply.

Figure 2 shows that in the period following the introduction of the first-time home buyer tax credit, prices in the medium-elasticity scenario increase by about 4% from their steady state level, as households take advantage of the one-time tax credit and shift forward their purchases of housing. This competes prices upwards. Correspondingly, these households leave the rental market, causing rents to drop by over 5%. The transaction volume in the housing market rises by over 40% in response to the tax credit. The construction sector reacts to the increase in prices, and the housing quantity jumps by over 1%, before depreciation gradually pushes it back to its initial steady state level. Transfers to households fall by about 2.5%, as the government reduces expenditures to finance the tax credit.

When the tax credit is removed, prices and transaction volumes fall somewhat below their initial steady state value for a number of years. This results from the fact that the tax credits primarily shifted demand forward in time, rather than creating substantial new demand for housing. Government revenues remain below their steady state level, since the additional purchases increased aggregate mortgage balances, and thus mortgage interest rate deductions. Over time, as the housing stock falls to its initial steady state level, prices and transfers also revert back.

Unsurprisingly, the price increase in response to the tax credit is smallest (and the increase in transaction volume is the largest) for the high-elasticity economy. The more the construction sector responds to the tax credit by increasing housing supply, the less the increase in demand translates into an increase in prices. Similarly, since the over-construction relative to the steady state optimum is increasing in $\epsilon$, the high-elasticity economy faces the largest and most prolonged decline in prices and rents following the removal of the tax credit.

Welfare effects of the first-time home buyer tax credit are overwhelmingly negative. Table 3 shows that following the introduction, about 90% of households in the medium-elasticity economy are worse off. All agents that do not purchase a house lose, since their transfers are reduced to finance the tax credit for buyers. This is also the case for renters that do not purchase, despite the temporary decline in rents. Even some first-time buyers are worse off, since the tax credit results in rising prices, and so does not allow them to purchase significantly more housing. The only winners among the households that started as owners are those that use the temporary price-increase to adjust their housing stock downwards.
(closer towards their optimal level), an adjustment that was prevented by adjustment costs before the tax credit. Compensating all households that are worse off such that they are indifferent to the introduction of the tax credits would involve a one-period cost of 0.75% of $\bar{y}$. We can also see that independently of the assumptions about $\epsilon$, compensating all households such that each is indifferent towards the tax credit (lump-sum taxing winners and subsidizing losers) would involve a net cost to the government. The tax credits therefore have negative aggregate welfare effects for the range of reasonable price elasticities of housing supply.

It is interesting to observe that the welfare effects are not monotone in the elasticity of housing supply. As elasticity increases, more initial homeowners and landlords suffer, since transfer payments decline by a larger amount. In addition, for higher values of $\epsilon$ the housing stock rises more, reducing the value of their housing assets more and for a longer period of time following the removal of the tax credit. Rents also decline by more for higher values
of $\epsilon$, which hurts landlords. On the other hand, the larger fall in rents explains why fewer initial renters loses as $\epsilon$ increases. In addition, since in the high-elasticity economy prices rise by the least amount, more renters take advantage of the tax credit offered to them and become homeowners. This is reflected in the larger increase in transaction volume in the high-elasticity economy compared to the low-elasticity economy.

### Table 3: Welfare Effects Immediately Following Tax Credit

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>First-Time Home Buyers</th>
<th>Repeat Homebuyers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\epsilon = 0$</td>
<td>$\epsilon = 2.5$</td>
</tr>
<tr>
<td></td>
<td>$\epsilon = 0$</td>
<td>$\epsilon = 2.5$</td>
</tr>
<tr>
<td>Households losing in new steady state (in %)</td>
<td>87.2 90.3 84.1</td>
<td>82.0 90.0 88.8</td>
</tr>
<tr>
<td>Initial owners losing (in %)</td>
<td>89.7 95.7 96.8</td>
<td>82.6 90.5 91.2</td>
</tr>
<tr>
<td>Initial renters losing (in %)</td>
<td>83.0 81.2 62.9</td>
<td>80.9 89.3 84.6</td>
</tr>
<tr>
<td>Initial landlords losing (in %)</td>
<td>67.3 72.9 75.1</td>
<td>57.2 83.7 85.2</td>
</tr>
<tr>
<td>Consumption needed to compensate losers (% of $y$)</td>
<td>0.66 0.75 0.74</td>
<td>0.34 0.66 0.64</td>
</tr>
<tr>
<td>Netgain after compensating all households (% of $y$)</td>
<td>-0.59 -0.72 -0.69</td>
<td>-0.20 -0.57 -0.54</td>
</tr>
</tbody>
</table>

Table 4 splits out the welfare effects for different types of agents. Unsurprisingly, the main age-income cells that benefit from the introduction of the tax credit are young, rich households. Those households take advantage of the tax credit to purchase a house, which allows them to consume significantly more housing in the first periods of their life. This outweighs the cost of having to inject new equity in the house after the price collapse in the period following the removal of the tax credit. Other agents generally lose from the tax credit - they receive lower transfers, and the one-time spike in house prices may delay their decision to trade-up, causing them to consume suboptimal quantities of housing.\(^{14}\)

### 7.2 Repeat Home Buyer Tax Credit

Price and quantity effects following the introduction of a tax credit for repeat home buyers are qualitatively similar to the effects following the introduction of tax credits for first time home buyers only. As shown in Figure 3, in the medium-elasticity economy prices increase by 4%, while transfers fall by almost 3%. The housing stock increases by about 1%, before slowly reverting back to the old steady state. In the period in which the tax credit is introduced, rents fall as agents leave the rental market. The response of trading volume to the tax credit is larger than for the first time home buyers tax credit, which is not surprising

\(^{14}\)One component that is not factored into this welfare analysis are the profits of the construction sector. Equation 13 showed that construction sector profits are a function of $p$. Following the introduction of the first-time home buyer tax credit, and the associated increase in prices, construction sector profits increase by about 13% above their steady-state level. In absolute terms, this increase is equivalent to 0.2% of $y$, and thus not sufficient to overturn our welfare conclusions.
### Table 4: Immediate Welfare Effects of the First Time Homebuyer Tax Credit

<table>
<thead>
<tr>
<th>Income Groups</th>
<th>20-24</th>
<th>25-29</th>
<th>30-34</th>
<th>35-39</th>
<th>40-44</th>
<th>45-49</th>
<th>50-54</th>
<th>55-59</th>
<th>60-64</th>
<th>65+</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st octant</td>
<td>-0.5</td>
<td>-0.4</td>
<td>-0.4</td>
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<td>-0.5</td>
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<td>-0.6</td>
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</tr>
<tr>
<td>2nd octant</td>
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<td>-0.7</td>
<td>-0.7</td>
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</tr>
<tr>
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<td>-1.0</td>
<td>-0.9</td>
<td>-1.0</td>
<td>-0.6</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>-1.0</td>
<td>-1.1</td>
<td>-1.4</td>
<td>-1.3</td>
<td>-0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6th octant</td>
<td>0.5</td>
<td>-0.2</td>
<td>-1.1</td>
<td>-1.0</td>
<td>-0.9</td>
<td>-1.1</td>
<td>-1.0</td>
<td>-1.1</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>-0.7</td>
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<td>-1.4</td>
<td>-1.3</td>
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<td>-1.3</td>
<td>-1.2</td>
<td></td>
</tr>
<tr>
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<td>-2.6</td>
<td>-2.3</td>
<td>-2.6</td>
<td>-2.5</td>
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<td>-2.5</td>
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</tr>
<tr>
<td><strong>Average</strong></td>
<td>0.0</td>
<td>-0.5</td>
<td>-0.8</td>
<td>-1.0</td>
<td>-1.1</td>
<td>-1.1</td>
<td>-1.2</td>
<td>-0.9</td>
<td>-0.4</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The table shows welfare changes in consumption equivalence units for different combinations of age and income. For example, the first number in the top left corner suggests that the average poor 20 – 24 year old would be prepared to reduce one-period consumption by about 0.5% of average income to avoid introduction of the tax credit. Each cell aggregates over households with the same immutable characteristics, but different holdings of housing and savings, and thus potentially confounds positive and negative welfare effects. The weights used to average welfare effects over different choices of $h$ and $s$ correspond to the relevant population density.

given the expanded eligibility.

Compared to the first-time home buyer tax credit, the repeat homebuyer tax credit appears preferable, even though the percentage of households losing is similar. For the first-time home buyer tax credits, a higher fraction of the losers are existing homeowners, and fewer are renters, at least in the medium and high elasticity economies. Homeowners on average are richer than renters, and require a larger absolute change in consumption to compensate them for a given fall in utility. The overall amount required to compensate all losers is therefore higher for the first-time home buyer tax credit.

In Table 5 we can also see that it is again the young, rich agents (most of whom would have purchased anyways) that benefit from the tax credit. The average loss for richer homeowners is smaller for the repeat buyers tax credit than for the first-time buyer credit, since some of these agents take advantage of the tax credit, allowing them to trade up.

### 7.3 Tax Credit - Discussion

The previous analysis suggests that temporary tax credits to encourage homeownership are a bad policy from a welfare perspective. Tax credits drive up prices and trading volumes, without allowing households to consume significantly more housing. Higher trading volumes increase the amount of deadweight loss in the economy generated by transaction costs. The reduction in transfers required to fund the tax credits leaves the large part of the population that does not purchase a house in that period worse off. In addition, many of the home
buyers that take advantage of the credit just shift their demand forward temporally, which leads to prices lower than the steady state for years following the expiration of the credit.

While we believe that the preceding analysis provides an important insight into the effects of the Obama administration’s tax credits, one needs to be aware of its limitation. One of the explicit aims of the tax credits was to support housing markets, including supporting house prices. This may have benefits that we do not model explicitly. For example, in the model economy there is no uncertainty about the price of housing. If, during the crisis, households had postponed planned home purchases due to uncertainty about future price development, the tax credit could be seen as a corrective tax, moving households back to their optimal level of homeownership.

Nevertheless, we believe that our model provides substantial insights into the welfare effects of the tax credits. It has shown that while tax credits are able to support housing markets by raising prices and volumes in the short-run, the temporal shifting of demand
will reduce housing demand in subsequent periods, which will lead to a fall of prices below the initial steady state. It also suggests that the Obama administration’s repeat buyer tax credit was preferable from a welfare perspective to its first-time home buyer tax credit.

8 Permanent Changes to the Tax Code

In this section we focus on analyzing possible permanent changes to the current U.S. policy regime. We consider prices, quantities and welfare, both across steady states and along the transition path between steady states. Section 8.1 analyzes the introduction of a tax on imputed rents. Section 8.2 considers a policy change that would remove all taxes on rental income, while removing any deductions associated with home purchases, such as the mortgage interest deduction. Both these experiments would end the unequal tax treatment of owner-occupied and rental housing.

8.1 Taxes on Imputed Rents

In the U.S. economy, there is no tax on the implicit rents that a property generates for an owner-occupier. Such a tax might seem unusual, but it exists in practice in a number of OECD countries as discussed in section 3.2. A method for calculating imputed rents in the U.S. is likely to be controversial. Nevertheless, the Bureau of Labor Statistics (BLS) already calculates an owner-equivalent rent series as an input into the CPI. This series could provide the basis for the calculation of imputed rents. In our first experiment, we solve for the stationary equilibrium in a model with taxes on imputed rents. Table 6 summarizes the steady-state effects of this experiment on prices and quantities under three different assumptions for the elasticity of housing supply.
### Table 6: Quantity + Price Effects in Steady State - Tax Imputed Rents

<table>
<thead>
<tr>
<th>Moment of Interest</th>
<th>Baseline</th>
<th>$\epsilon = 0$</th>
<th>$\epsilon = 2.5$</th>
<th>$\epsilon = 6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Price (normalized)</td>
<td>1.000</td>
<td>0.840</td>
<td>0.947</td>
<td>0.973</td>
</tr>
<tr>
<td>Rental Price (normalized)</td>
<td>1.000</td>
<td>0.905</td>
<td>1.013</td>
<td>1.037</td>
</tr>
<tr>
<td>Price-Rent Ratio</td>
<td>21.16</td>
<td>19.63</td>
<td>19.79</td>
<td>19.86</td>
</tr>
<tr>
<td>Housing Stock (normalized)</td>
<td>1.000</td>
<td>1.000</td>
<td>0.875</td>
<td>0.853</td>
</tr>
<tr>
<td>Rental Market (normalized)</td>
<td>1.000</td>
<td>2.536</td>
<td>2.381</td>
<td>2.331</td>
</tr>
<tr>
<td>Homeownership Rate (in %)</td>
<td>68.0</td>
<td>43.3</td>
<td>39.9</td>
<td>39.3</td>
</tr>
<tr>
<td>Share of Landlords (in %)</td>
<td>14.9</td>
<td>17.2</td>
<td>19.4</td>
<td>19.7</td>
</tr>
<tr>
<td>Average LTV (in %)</td>
<td>36.8</td>
<td>11.1</td>
<td>11.4</td>
<td>11.7</td>
</tr>
<tr>
<td>Capital income tax revenue (% of $y$)</td>
<td>0.53</td>
<td>0.50</td>
<td>0.49</td>
<td>0.49</td>
</tr>
<tr>
<td>Rental income tax revenue (% of $y$)</td>
<td>0.24</td>
<td>1.59</td>
<td>1.55</td>
<td>1.54</td>
</tr>
<tr>
<td>Tax Loss: mortgage interest deduction (% of $y$)</td>
<td>0.54</td>
<td>0.17</td>
<td>0.17</td>
<td>0.18</td>
</tr>
<tr>
<td>Tax Loss: non-taxed imputed rents (% of $y$)</td>
<td>1.43</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Note:** The table shows moments of interest in the stationary equilibrium of the baseline model as well as the experiment with taxes on imputed rents ($\Psi_1 = 0$).

### Prices and Quantities:
A tax on imputed rents reduces the incentives of being a homeowner. For the intermediate elasticity calibration ($\epsilon = 2.5$), the homeownership rate drops by 28.1 percentage points, from 68% to 39.9%. Correspondingly, house prices fall by 5.3% as more households choose to rent rather than to buy. This drop in prices comes despite a significant decline in the housing stock of 12.5%. As expected, we can see that with a more elastic housing supply, the housing stock declines by more. Consequently, house prices need to fall less to re-establish equilibrium in the housing market. The smaller the price decrease, the larger the fall in the homeownership rate resulting from the taxation of imputed rents.

Despite a small increase in rents, the absolute size of the rental market more than doubles in size. This is driven by the removal of the asymmetry in the tax treatment of rental and owner-occupied housing. Homeowners are now more willing to lease out some of their housing stock, since they no longer give up the tax benefit of owner-occupying. Young agents now purchase later and consume more rented housing. It is primarily the richest agents aged 35 and older that own a larger housing stock in the new alternative steady state, and put a significant fraction of their property on the rental market. The share of landlords in the economy consequently increases from 14.9% to 19.4% after the removal of the tax-wedge. This means that in the new steady state, more than half the homeowners also are landlords. For the high-$\epsilon$ economy, with higher rents, the increase in the fraction of landlords is even bigger. These results suggest that in the baseline steady state, the tax wedge induced homeowners to overconsume housing service out of their owned housing stock. Consistent

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15Unless otherwise noted, the discussion of results will focus on the intermediate elasticity case of $\epsilon = 2.5$. Where relevant, we also discuss how outcomes change with the price elasticity.
with this, in the new steady state of the medium-elasticity economy, the housing share in total consumption falls to 12.1%, from 14.1% in the baseline steady state. The ratio of the average size of owner-occupied housing to renter-occupied housing falls to 2.26, from 2.72.

Average loan-to-value ratios in the economy fall significantly. This happens because the set of homeowners now consists primarily of wealthy households that have sufficient resources to cash-purchase their housing. The lower-middle income households that have high loan-to-value ratios in the baseline steady state are renters in the new steady state. Government revenues increase by 8.2%. Most of this increase comes from the taxation of imputed rents. In fact, in the medium-elasticity economy revenues increase by 1.62% of $\bar{y}$, which is more than the tax-loss due to the non-taxation of imputed rents in the baseline steady state, which amounted to 1.43% of $\bar{y}$. Lower loan-to-value ratios in the new steady state lead to lower deductions of mortgage interest payments, and hence higher tax revenue.

**Welfare Comparisons:** The following section compares the welfare of households in the initial steady state with households of identical state variables in the alternative steady state. As described in section 5, we use expected discounted utility, measured in one-time consumption equivalent units, as our welfare criterion.

**Table 7: Welfare Comparison - Tax on Imputed Rents**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Between Steady States</th>
<th>Along Transition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\epsilon = 0$</td>
<td>$\epsilon = 2.5$</td>
</tr>
<tr>
<td>Households losing in new steady state (in %)</td>
<td>32.0</td>
<td>33.4</td>
</tr>
<tr>
<td>Initial owners losing (in %)</td>
<td>51.2</td>
<td>53.5</td>
</tr>
<tr>
<td>Initial renters losing (in %)</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>Initial landlords losing (in %)</td>
<td>57.8</td>
<td>50.9</td>
</tr>
<tr>
<td>Consumption needed to compensate losers (% of $\bar{y}$)</td>
<td>1.19</td>
<td>1.05</td>
</tr>
<tr>
<td>Netgain after compensating all households (% of $\bar{y}$)</td>
<td>3.55</td>
<td>1.39</td>
</tr>
</tbody>
</table>

Table 7 shows that in the medium-elasticity calibration about 66.6% of households are better off in the new steady state than households with the same state variables in the old steady state. Compensating the households that are worse off in an economy with taxes on imputed rents such that they would be willing to switch position with an agent of the same state variables in new steady state, would involve a one-period cost of 1.05% of $\bar{y}$. When lump-sum taxing winners and compensating losers to make such a switch welfare-neutral, the government would raise revenues equivalent to a one-time gain of 1.39% of $\bar{y}$.

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16This feature of our model can also be found in the data. Poterba and Sinai (2008) find that average loan-to-value ratios peak for the households with an annual income of $75,000 – $125,00 at 47.4%. Households with annual income of over $250,000 have average loan-to-value ratios of 29.4%, which is well below the economy-wide average.
Interestingly, the number of households losing in the new steady state is increasing in the housing supply elasticity. The higher rents in high-\(\epsilon\) economies increase the tax burden due to the taxation of imputed rents for all households. This more than outweighs the lower capital losses for homeowners due to smaller price declines in high-\(\epsilon\) economies. On the other hand, relative to all homeowners, fewer landlords lose as \(\epsilon\) increases. While higher rents increase the cost of owner-occupying due to the newly introduced tax, they also increase the benefits of being a landlord. The low rents in the \(\epsilon = 0\) economy also explain why the resources required to compensate losers are higher than in the \(\epsilon = 2.5\) economy, despite the fact that fewer households lose. In particular, the comparatively rich landlords are significantly worse off in the zero-elasticity economy since both the value of their housing stock and their rental income fall. Consequently, they require a large consumption compensation to make them indifferent between staying in the old steady state and switching with a similar agent in the new steady state.

Table 8 shows the average consumption equivalent welfare compensation for a switch to the steady state with taxes on imputed rents for different age groups and levels of idiosyncratic productivity. In the new steady state, renters generally consume both more housing services and more consumption goods than before. Their income increases through higher transfers financed by tax raised from owner-occupied housing, which more than offsets the small increase in rents. Essentially all renters are better off in the new steady state.

Rich homeowners generally prefer the status quo. Those agents desire to owner-occupy the largest amount of housing, and benefit least from the increase in transfer payments resulting from increased tax revenue. It is primarily the housing consumption of those agents that falls to accommodate the decline in housing stock (it can drop by over 20%). Despite the rental revenue they now receive as landlords, tax payments on owner-occupied units mean that these agents are only able to marginally increase non-housing consumption.

Table 8: Stationary Welfare Effects – Model with Tax on Imputed Rents (\(\epsilon = 2.5\))

<table>
<thead>
<tr>
<th>Income Groups</th>
<th>20-24</th>
<th>25-29</th>
<th>30-34</th>
<th>35-39</th>
<th>40-44</th>
<th>45-49</th>
<th>50-54</th>
<th>55-59</th>
<th>60-64</th>
<th>65+</th>
<th>Average</th>
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</thead>
<tbody>
<tr>
<td>1st octant</td>
<td>5.2</td>
<td>5.6</td>
<td>5.7</td>
<td>5.5</td>
<td>5.1</td>
<td>4.7</td>
<td>3.9</td>
<td>2.7</td>
<td>1.3</td>
<td>-0.3</td>
<td></td>
</tr>
<tr>
<td>2nd octant</td>
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<td>4.7</td>
<td>3.6</td>
<td>2.5</td>
<td>1.1</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>3rd octant</td>
<td>4.7</td>
<td>6.1</td>
<td>6.5</td>
<td>5.8</td>
<td>5.1</td>
<td>4.0</td>
<td>2.8</td>
<td>2.1</td>
<td>1.1</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>4th octant</td>
<td>4.6</td>
<td>6.2</td>
<td>6.4</td>
<td>5.3</td>
<td>4.2</td>
<td>3.1</td>
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<td>1.2</td>
<td>0.4</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>5th octant</td>
<td>4.5</td>
<td>6.1</td>
<td>5.6</td>
<td>4.3</td>
<td>3.4</td>
<td>2.2</td>
<td>0.9</td>
<td>0.5</td>
<td>-0.3</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>6th octant</td>
<td>4.4</td>
<td>5.1</td>
<td>5.2</td>
<td>3.6</td>
<td>0.7</td>
<td>-0.5</td>
<td>-1.0</td>
<td>-1.6</td>
<td>-2.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>7th octant</td>
<td>3.8</td>
<td>4.6</td>
<td>1.5</td>
<td>0.2</td>
<td>-0.9</td>
<td>-2.2</td>
<td>-2.9</td>
<td>-3.4</td>
<td>-3.3</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>8th octant</td>
<td>3.6</td>
<td>0.3</td>
<td>-1.4</td>
<td>-4.2</td>
<td>-6.0</td>
<td>-7.4</td>
<td>-8.0</td>
<td>-7.9</td>
<td>-7.1</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>4.4</td>
<td>5.0</td>
<td>4.5</td>
<td>3.3</td>
<td>2.1</td>
<td>1.1</td>
<td>0.1</td>
<td>-0.5</td>
<td>-1.1</td>
<td>-0.3</td>
<td></td>
</tr>
</tbody>
</table>
Transition Periods: Figure 4 illustrates the development of prices and quantities during the perfect foresight transition to the steady state in which imputed rents are taxed for the medium-elasticity economy. Following the reform, households with large houses attempt to sell or rent out parts of their housing stock, since the new tax reduces the incentive to owner-occupy. House prices plummet and fall by about 12% in the first period after the introduction of the tax on owner-occupied housing. The housing stock declines, but does not immediately adjust to its new steady state value. As the housing stock approaches its new steady state over time, house prices recover and reach their new equilibrium level – about 5% below the initial price level – after approximately 50 years. This development is intuitive. After the removal of the preferential treatment of owner-occupied housing, the aggregate demand for housing falls. Since the supply of housing units is relatively inelastic in the short-run, house prices fall significantly below their new long-run equilibrium level in the periods following the introduction of the tax on imputed rents. Over time, depreciation naturally leads to a decline of the housing stock to its new steady state level, and prices recover. Figure 4 further highlights that rents actually fall initially, before increasing to their new steady state value about 1% above the baseline steady state.

Figure 4: Transition Dynamics – Tax on Imputed Rents, \(\epsilon = 2.5\)

The second half of Table 7 summarizes the welfare effects immediately following the introduction of the tax on imputed rents. We can see that about 40.4% of households (all of them homeowners) are worse off following the introduction of such a tax in the medium-elasticity economy. In the low-\(\epsilon\) economy it is particularly the landlords that suffer more in
the immediate aftermath of the policy change than in a comparison of steady states, due to
the initial decline in rents. It would take a one-time expense of 1.46% of $y$ to compensate all
losers from the introduction of taxes on imputed rents. This is almost 50% higher than the
figure obtained by comparing steady states. However, if it were possible to also lump-sum
tax all households who benefit from the policy shift, a welfare-neutral shift would yield the
government 1.23% of $y$.

Table 9 shows the average consumption change required to compensate agents of different
immutable characteristics for the introduction of the policy change. Along the transition
path, richer households generally lose as a result of the introduction of the new tax, since
as owners of large houses they suddenly find themselves holding sub-optimally large housing
stock. The amount of owner-occupied housing they planned to consume under the old
policy regime now comes with an additional tax burden and these households will thus be
looking to sell or rent out part of their real estate. Since the housing stock does not adjust
downward immediately, this generates substantial supply overhang in the rental market.
Falling rents make it more difficult for households to reduce their tax-exposure by increasing
the size of housing leased to other households. Consequently, the richest agents reduce both
housing and non-housing consumption in the period following the introduction of the tax on
imputed rents. However, the immediate welfare loss to rich homeowners is smaller than the
loss implied by the comparison of steady states. This is because rents fall initially, reducing
imputed rents, and hence the tax bill. The initial decline in rents also explains why tax
revenues and transfers only adjust slowly to their new steady state value.

Another important welfare effect comes through the decline in prices. Equation (8)
ensures that an household’s equity in its home is bounded from below by the downpayment
requirement. When prices fall, agents who hold high loan-to-value mortgages will face a
margin call, which requires them to inject new equity into the home.\textsuperscript{17}

Renters from the initial steady state continue to gain from the reform, even more so than
in the steady-state comparison. The price overshoot allows those agents to significantly
increase their housing consumption, primarily as renters of larger homes. They further-
more benefit from the increase in the lump-sum transfer payments in period $t$ following the
introduction of the tax on owner-occupied housing (see Figure 4).

\textsuperscript{17}In other words, the model does not allow homeowners to default on their mortgages. In reality, no mortgages
explicitly include such a margin call, and following the 2007 crisis in the U.S. housing market, many home-
owners were under water. In recourse states, where homeowners cannot just walk away from their mortgage,
being under water has large negative welfare effects, similar to those generated in our model. In non-recourse
states, the direct effects on households through the “margin-call channel” may not be as sizable as the model
suggests. Nevertheless, mortgage default in non-recourse states has other adverse welfare effects.
<table>
<thead>
<tr>
<th>Income Age Groups</th>
<th>20-24</th>
<th>25-29</th>
<th>30-34</th>
<th>35-39</th>
<th>40-44</th>
<th>45-49</th>
<th>50-54</th>
<th>55-59</th>
<th>60-64</th>
<th>65+</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st octant</td>
<td>5.2</td>
<td>5.7</td>
<td>5.9</td>
<td>5.6</td>
<td>5.0</td>
<td>4.2</td>
<td>3.0</td>
<td>1.6</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>2nd octant</td>
<td>5.1</td>
<td>6.3</td>
<td>6.7</td>
<td>6.0</td>
<td>5.2</td>
<td>4.1</td>
<td>2.6</td>
<td>1.4</td>
<td>-0.2</td>
<td>-</td>
</tr>
<tr>
<td>3rd octant</td>
<td>5.0</td>
<td>6.6</td>
<td>7.0</td>
<td>5.9</td>
<td>4.8</td>
<td>3.4</td>
<td>1.8</td>
<td>1.0</td>
<td>-0.3</td>
<td>-</td>
</tr>
<tr>
<td>4th octant</td>
<td>4.9</td>
<td>6.9</td>
<td>7.0</td>
<td>5.3</td>
<td>4.1</td>
<td>2.5</td>
<td>1.0</td>
<td>0.4</td>
<td>-0.5</td>
<td>-</td>
</tr>
<tr>
<td>5th octant</td>
<td>5.0</td>
<td>7.0</td>
<td>6.3</td>
<td>4.6</td>
<td>3.5</td>
<td>2.1</td>
<td>0.4</td>
<td>-0.1</td>
<td>-1.2</td>
<td>-</td>
</tr>
<tr>
<td>6th octant</td>
<td>5.1</td>
<td>6.1</td>
<td>6.3</td>
<td>4.4</td>
<td>1.0</td>
<td>-0.7</td>
<td>-1.4</td>
<td>-2.3</td>
<td>-2.7</td>
<td>-</td>
</tr>
<tr>
<td>7th octant</td>
<td>4.8</td>
<td>6.2</td>
<td>2.5</td>
<td>0.7</td>
<td>-0.5</td>
<td>-2.0</td>
<td>-3.0</td>
<td>-4.0</td>
<td>-4.4</td>
<td>-</td>
</tr>
<tr>
<td>8th octant</td>
<td>6.4</td>
<td>2.2</td>
<td>2.4</td>
<td>-1.4</td>
<td>-3.2</td>
<td>-5.2</td>
<td>-6.0</td>
<td>-6.1</td>
<td>-7.2</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td>5.2</td>
<td>5.9</td>
<td>5.5</td>
<td>3.9</td>
<td>2.5</td>
<td>1.0</td>
<td>-0.2</td>
<td>-1.0</td>
<td>-2.1</td>
<td>-1.3</td>
</tr>
</tbody>
</table>

8.2 No Taxes, No Deductions

The second experiment also removes the asymmetry in the tax treatment of owner-occupied and rental housing. Instead of taxing both forms of housing at the same rate, and allowing the same deductions, as we did in section 8.1, in this experiment we tax neither the returns from owner-occupied housing, nor the rents received from rental housing. In addition, we remove all deductions associated with homeownership, in particular any deductions for mortgage interest payments and depreciation of rented property.

**Prices and Quantities:** Table 10 shows that in the new steady state house prices are lower than in the baseline scenario, though they do not fall by as much as in the first experiment. On the one hand, the removal of mortgage interest deduction makes homeownership less attractive, at least for young, credit-constrained households that require a large mortgage. On the other hand, the removal of taxes on rental income increases the attractiveness of real estate, in particular for those households that choose to become landlords.

In the new steady state, landlords no longer pay taxes on their rental income, which allows them to supply rental services at lower prices. Rents hence decline by 8% in the medium-elasticity calibration. The share of landlords in the economy increases to 18.4%. It is particularly rich agents, who are less reliant on mortgage financing, who own a larger housing stock which they rent out. The absolute size of the rental market increases significantly. Correspondingly, the homeownership rate falls to 42.7%. Since mortgages are now more expensive post-tax, and the composition of owners shifts towards more wealthy households, the economy-wide loan-to-value ratio falls to 13.4%. In line with the decline in house prices, the housing stock falls by about 3.9%. The relative size of owner-occupied to renter-occupied housing declines to 2.24 from 2.72 in the baseline steady state, while the housing share in consumption falls to 12.5%. These declines are comparable to those of experiment 1, in which we also removed the asymmetric tax-treatment of owner-occupied housing.
Total transfers increase by 1.2%, which suggests that the revenue gain from removing the mortgage interest deduction exceeds the loss from eradicating the tax on rental income. This is confirmed by comparing the magnitude of the tax-loss due to mortgage-interest deductibility with the revenue from tax on rental income in the baseline steady state.\footnote{The magnitude of the mortgage interest deduction tax loss in the model is similar to that observed in the data. In 2009, the mortgage interest deduction cost the U.S. Treasury a total of \$86 billion. This is about 0.7% of total personal income in that year.}

**Table 10:** Quantity + Price Effects in Steady State - No Taxes, No Deductions

<table>
<thead>
<tr>
<th>Moment of Interest</th>
<th>Baseline</th>
<th>$\epsilon = 0$</th>
<th>$\epsilon = 2.5$</th>
<th>$\epsilon = 6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Price (normalized)</td>
<td>1.000</td>
<td>0.948</td>
<td>0.984</td>
<td>0.991</td>
</tr>
<tr>
<td>Rental Price (normalized)</td>
<td>1.000</td>
<td>0.889</td>
<td>0.920</td>
<td>0.927</td>
</tr>
<tr>
<td>Price-Rent Ratio</td>
<td>21.16</td>
<td>22.57</td>
<td>22.63</td>
<td>22.63</td>
</tr>
<tr>
<td>Housing Stock (normalized)</td>
<td>1.000</td>
<td>1.000</td>
<td>0.961</td>
<td>0.950</td>
</tr>
<tr>
<td>Rental Market (normalized)</td>
<td>1.000</td>
<td>2.463</td>
<td>2.435</td>
<td>2.397</td>
</tr>
<tr>
<td>Homeownership Rate (in %)</td>
<td>68.0</td>
<td>44.1</td>
<td>42.7</td>
<td>42.6</td>
</tr>
<tr>
<td>Share of Landlords (in %)</td>
<td>14.9</td>
<td>17.7</td>
<td>18.4</td>
<td>18.5</td>
</tr>
<tr>
<td>Average LTV (in %)</td>
<td>36.8</td>
<td>13.8</td>
<td>13.4</td>
<td>13.4</td>
</tr>
<tr>
<td>Transfers (% of $\bar{y}$)</td>
<td>19.71</td>
<td>19.95</td>
<td>19.94</td>
<td>19.95</td>
</tr>
<tr>
<td>Capital income tax revenue (% of $\bar{y}$)</td>
<td>0.53</td>
<td>0.47</td>
<td>0.46</td>
<td>0.47</td>
</tr>
<tr>
<td>Rental income tax revenue (% of $\bar{y}$)</td>
<td>0.24</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Tax Loss: mortgage interest deduction (% of $\bar{y}$)</td>
<td>0.54</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Tax Loss: non-taxed imputed rents (% of $\bar{y}$)</td>
<td>1.43</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Note:** The table shows moments of interest in the stationary equilibrium of the baseline model as well as the experiment with no taxes on rental income ($\tau^r = 0$) and no mortgage interest payment deduction ($\Psi_2 = 0$).

**Welfare Comparisons:** Table 11 shows that about 17.8% of households lose in the new medium-elasticity steady state. The consumption increase required to compensate them for their welfare loss amounts to about 0.33% of $\bar{y}$. Unlike in the first experiment, the percentage of people who lose in the new steady state is decreasing in $\epsilon$. This is because in the higher-$\epsilon$ economy prices fall by less, reducing the capital loss faced by homeowners.\footnote{In the first experiment this effect was outweighed by the increasing cost of the tax on imputed rents.} As elasticity increases, rents increase by more following the reform. The number of landlords who lose therefore falls even more than the number of losing homeowners in general. Landlords do not only benefit from the smaller capital loss, but can also increase their rental income. The welfare-increase of renters is smaller for higher $\epsilon$. Higher rents increase their current housing cost, and the smaller drop in prices makes it more expensive for them to eventually become homeowners. However, on balance all renters still benefit due to increase in steady-state transfers, even in the high-elasticity economy.

Table 12 shows that the primary losers are those medium-income households that have
Table 11: Welfare Comparison: No taxes, no deductions

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Between Steady States</th>
<th>Along Transition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\epsilon = 0$</td>
<td>$\epsilon = 2.5$</td>
</tr>
<tr>
<td>Households losing in new steady state (in %)</td>
<td>17.8</td>
<td>17.2</td>
</tr>
<tr>
<td>Initial owners losing (in %)</td>
<td>28.5</td>
<td>27.6</td>
</tr>
<tr>
<td>Initial renters losing (in %)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Initial landlords losing (in %)</td>
<td>33.2</td>
<td>19.1</td>
</tr>
<tr>
<td>Consumption needed to compensate losers (% of $\overline{y}$)</td>
<td>0.32</td>
<td>0.33</td>
</tr>
<tr>
<td>Netgain after compensating all households (% of $\overline{y}$)</td>
<td>2.16</td>
<td>1.64</td>
</tr>
</tbody>
</table>

Recently bought and mortgage-financed a house, and thus suffer significantly from the removal of mortgage interest deductibility.\textsuperscript{20} These agents do not yet own enough housing to supply units to the rental market, and hence do not benefit from the removal of tax on rental income. Older and richer households often gain more than middle-income households, making the welfare effects non-monotonic in income. These households are less reliant on mortgage-financing, and thus suffer less from the removal of mortgage interest deductibility. At the same time, they have the resources to own rental property, and thus benefit from the removal of taxes on rental income.

Table 12: Stationary Welfare Effects – No Taxes, No Deductions ($\epsilon = 2.5$)

<table>
<thead>
<tr>
<th>Income Groups</th>
<th>20-24</th>
<th>25-29</th>
<th>30-34</th>
<th>35-39</th>
<th>40-44</th>
<th>45-49</th>
<th>50-54</th>
<th>55-59</th>
<th>60-64</th>
<th>65+</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st octant</td>
<td>1.5</td>
<td>1.7</td>
<td>1.8</td>
<td>1.6</td>
<td>1.4</td>
<td>1.0</td>
<td>0.6</td>
<td>0.2</td>
<td>0.1</td>
<td>0.9</td>
</tr>
<tr>
<td>2nd octant</td>
<td>1.6</td>
<td>2.0</td>
<td>2.1</td>
<td>1.6</td>
<td>1.2</td>
<td>0.7</td>
<td>0.2</td>
<td>0.1</td>
<td>0.2</td>
<td>–</td>
</tr>
<tr>
<td>3rd octant</td>
<td>1.6</td>
<td>2.1</td>
<td>2.0</td>
<td>1.3</td>
<td>0.8</td>
<td>0.3</td>
<td>-0.1</td>
<td>0.1</td>
<td>0.5</td>
<td>–</td>
</tr>
<tr>
<td>4th octant</td>
<td>1.6</td>
<td>2.2</td>
<td>1.7</td>
<td>0.7</td>
<td>0.3</td>
<td>-0.1</td>
<td>-0.1</td>
<td>0.3</td>
<td>0.7</td>
<td>–</td>
</tr>
<tr>
<td>5th octant</td>
<td>1.7</td>
<td>1.9</td>
<td>0.7</td>
<td>-0.2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.3</td>
<td>0.9</td>
<td>1.1</td>
<td>–</td>
</tr>
<tr>
<td>6th octant</td>
<td>1.8</td>
<td>0.7</td>
<td>0.0</td>
<td>-0.2</td>
<td>0.7</td>
<td>1.1</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>–</td>
</tr>
<tr>
<td>7th octant</td>
<td>1.7</td>
<td>-0.3</td>
<td>0.5</td>
<td>1.9</td>
<td>3.0</td>
<td>3.9</td>
<td>4.0</td>
<td>3.3</td>
<td>2.7</td>
<td>–</td>
</tr>
<tr>
<td>8th octant</td>
<td>2.7</td>
<td>3.1</td>
<td>7.6</td>
<td>9.6</td>
<td>11.0</td>
<td>11.3</td>
<td>11.3</td>
<td>10.4</td>
<td>6.7</td>
<td>–</td>
</tr>
<tr>
<td>Average</td>
<td>1.8</td>
<td>1.7</td>
<td>2.0</td>
<td>2.0</td>
<td>2.3</td>
<td>2.3</td>
<td>2.2</td>
<td>2.1</td>
<td>1.7</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Transition Periods: The transition dynamics for experiment 2 look similar to those for experiment 1. Figure 5 shows that house prices initially drop by about 4% in the medium-elasticity environment, before recovering to their new steady state level, about 2% below the baseline steady state, after about 25 – 30 years. As in the previous experiment, this

\textsuperscript{20}In Table 12 these agents fail to consistently show up with a negative sign, since the overall welfare effects on their age/productivity cell are dominated by the welfare increases of renters with the same immutable characteristics. In our model, agents with the same income and age characteristics make different choices due the fact that they face different income histories, and thus a different portfolio of savings and housing.
overshooting of house prices is explained by the fact that the housing stock does not adjust to its new steady state level immediately. Rents also overshoot, though not by as much.

Figure 5: Transition Dynamics – No Taxes, No Deductions, $\epsilon = 2.5$

As was the case with the steady state comparison, the agents that lose from the removal of taxes on rental income and deductions for mortgage interest are middle-income homeowners who recently purchased a home with a large mortgage. These agents now lose the ability to deduct their mortgage interest payments from their taxes, while facing significant margin calls. Richer and older agents fare better, since they have the financial resources available to purchase housing to lease to other households. This is attractive for two reasons: Firstly, the rental income derived from these units is no longer taxed. Secondly, housing assets are known to appreciate along the perfect foresight transition path.

When comparing the steady state welfare effects of experiment 1 and experiment 2, we find that in steady state, experiment 2 appears more appealing from an aggregate welfare perspective. This continues to be the case along the transition path. In Table 11 we can see that for $\epsilon = 2.5$, about 24.9% of households would be worse off in the period directly following the removal of taxes on imputed rents and deductions for mortgage interest payments. This is significantly fewer households than the 40.3% that would be worse off in experiment 1, when we introduced taxes on imputed rents. Making the change welfare neutral for all households by taxing winners and subsidizing losers amounts to a net gain 1.83% of $\overline{y}$, compared to a gain of 1.23% of $\overline{y}$ following the introduction of taxes on imputed rents. However, in experiment 2 the cost of the policy change is mainly carried by middle-income households,
Table 13: Immediate Welfare Effects – No Taxes, No Deductions (\(\epsilon = 2.5\))

<table>
<thead>
<tr>
<th>Income Groups</th>
<th>Age Groups</th>
<th>20-24</th>
<th>25-29</th>
<th>30-34</th>
<th>35-39</th>
<th>40-44</th>
<th>45-49</th>
<th>50-54</th>
<th>55-59</th>
<th>60-64</th>
<th>65+</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st octant</td>
<td></td>
<td>1.8</td>
<td>2.0</td>
<td>2.1</td>
<td>1.9</td>
<td>1.6</td>
<td>1.1</td>
<td>0.6</td>
<td>0.2</td>
<td>-0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>2nd octant</td>
<td></td>
<td>1.8</td>
<td>2.3</td>
<td>2.4</td>
<td>1.9</td>
<td>1.3</td>
<td>0.7</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
<td>–</td>
</tr>
<tr>
<td>3rd octant</td>
<td></td>
<td>1.9</td>
<td>2.5</td>
<td>2.3</td>
<td>1.4</td>
<td>0.9</td>
<td>0.2</td>
<td>-0.2</td>
<td>0.1</td>
<td>0.3</td>
<td>–</td>
</tr>
<tr>
<td>4th octant</td>
<td></td>
<td>1.9</td>
<td>2.5</td>
<td>2.0</td>
<td>0.7</td>
<td>0.3</td>
<td>-0.2</td>
<td>-0.3</td>
<td>0.2</td>
<td>0.6</td>
<td>–</td>
</tr>
<tr>
<td>5th octant</td>
<td></td>
<td>2.0</td>
<td>2.3</td>
<td>0.9</td>
<td>-0.2</td>
<td>-0.1</td>
<td>-0.1</td>
<td>0.2</td>
<td>0.8</td>
<td>1.1</td>
<td>–</td>
</tr>
<tr>
<td>6th octant</td>
<td></td>
<td>2.2</td>
<td>1.1</td>
<td>0.2</td>
<td>0.0</td>
<td>0.8</td>
<td>1.1</td>
<td>1.6</td>
<td>1.5</td>
<td>1.5</td>
<td>–</td>
</tr>
<tr>
<td>7th octant</td>
<td></td>
<td>2.1</td>
<td>0.1</td>
<td>0.8</td>
<td>2.2</td>
<td>3.3</td>
<td>3.9</td>
<td>4.0</td>
<td>3.3</td>
<td>2.5</td>
<td>–</td>
</tr>
<tr>
<td>8th octant</td>
<td></td>
<td>3.5</td>
<td>3.5</td>
<td>8.9</td>
<td>10.7</td>
<td>12.3</td>
<td>12.4</td>
<td>12.3</td>
<td>11.4</td>
<td>7.2</td>
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<tr>
<td>Average</td>
<td></td>
<td>2.2</td>
<td>2.1</td>
<td>2.4</td>
<td>2.3</td>
<td>2.5</td>
<td>2.4</td>
<td>2.3</td>
<td>2.2</td>
<td>1.6</td>
<td>1.0</td>
</tr>
</tbody>
</table>

while in experiment 1 the losers were generally rich households.

9 Conclusion

This paper considers the effects of government interventions in the housing market on prices, quantities and welfare in a heterogeneous agent, overlapping-generations general equilibrium framework. We explicitly model the supply of rental units by households, which allows us to capture the effect of changes in rents on all households’ budget constraints. It also allows us to explicitly incorporate the effects of transaction costs into our analysis.

We first consider the effects of a first-time home buyer tax credit and a repeat home buyer tax credit. We find that these tax credits are successful at temporarily raising prices and transaction volumes. However, in the periods following the expiration of the tax credit, house prices and trading volumes fall below their steady state values, before slowly recovering. The welfare effects of home buyer tax credits are negative for most households. When comparing the two credits, we find the repeat home buyer tax credit to be superior from a welfare perspective.

We also consider two changes to the tax framework that would remove the asymmetric tax treatment of owner-occupied and rental housing: (i) the introduction of taxes on imputed rents, and (ii) the simultaneous removal of taxes on rental income and the removal of mortgage interest deductibility. We find that both policy changes lead to aggregate welfare gains, both when comparing steady states, as well as when comparing immediate welfare responses. The welfare gains appear larger when only comparing steady state equilibria. In addition, from an aggregate welfare perspective, the removal of taxes on rental income and mortgage interest deductions appears superior. However, the distribution of gains and losses for the two policy changes is different: While the introduction of a tax on imputed rents...
harm primarily the richest agents, the removal of mortgage interest deduction and the tax on rental income harms middle-income agents. Therefore, the preferred tool for removing the asymmetry in the tax treatment depends on a trade-off between aggregate and distributional objectives, as well as the feasibility of implementing a lump-sum compensation scheme.

References


Hoeck, M.P. and Radloff, S.E. (2007): Taxing Owner-Occupied Housing: Comparing the Netherlands to other European Union Countries, MPRA Paper No. 5876


A Not for Publication: Analytical Appendix

A.1 Consumption-Renting Decision for given House Size

Solving the model is computationally intensive. However, a significant simplification of the numerical problem can be achieved by first solving for two control variables in a static problem. For a given combination of state variables, savings and tenure choice, the allocation of resources to the consumption of the numeraire good and the consumption of housing services can be pinned down by a simple first order condition.

First, consider the problem of an agent who decides not to buy a house, but instead to rent. For a given set of state variables and given the savings choice, the problem of how to allocate resources to consumption and housing services is static. When we denote the resources available for consumption and renting by $X$, the problem becomes:

$$\max_{\tilde{h}} \left\{ u(c, \tilde{h}) \right\}$$

s.t.: $c + p^r \tilde{h} \leq X$ (20)

The optimal allocation of resources equates the marginal utility that can be derived from the two uses of funds, $p^r u_C = u_H$. Given the functional form for the utility function we have assumed in (1), this allows us to derive the demand for housing services (and thus the rental demand) for this particular agent as:

$$\tilde{h}_{\text{renter}}^* = \left( \frac{\omega \lambda}{p^r} \right)^{\frac{1}{1-a}} \frac{c}{\lambda} = X \left( p^r + \lambda \left( \frac{\omega \lambda}{p^r} \right)^\frac{1}{a-1} \right)^{-1}$$ (22)

Second, consider the case of an agent who chooses to buy a house of size $h$. For a given set of states and controls, we can again determine the resources available for consumption and housing services. For convenience, we first calculate those resources for the hypothetical case where the agent decides to rent out his home completely. Again, denote those resources by $X$. This implies that the agent rents out the complete house and then uses the market to acquire the housing services she desires. Here, the problem is exactly analogous to the renter problem and the interior solution is then also given by (22).

However, an agent with significant financial wealth who owns a small house might run into the constraint given by equation (2). In that case, the homeowner is trying to rent additional housing units which we do not allow by assumption. Hence, the owners choice of
housing services can be expressed as:
\[
\tilde{h}_{\text{owner}}^* = \min \left\{ h, X \left( p^r + \lambda \left( \frac{\omega \lambda}{p^r} \right) \right)^{\frac{1}{1-\alpha}} \right\}.
\]

**A.2 Policy Alternatives in the Budget Constraint**

For notational convenience, we start with the case of no deductions. This is equivalent to setting \( \Psi_1 = \Psi_2 = 0 \) in equation (15). That is, mortgage interest payments cannot be deducted from the tax bill and the tax on rental income is levied both on real rental income as well as on imputed rental income from owner-occupied housing. It is important to note that current U.S. policy is given by \( \Psi_1 = \Psi_2 = 1 \). For both potential deductions considered in this paper, we illustrate the effect on the household’s budget constraint both in the homeowner case and in the renter case. We ensure that overall tax payments of each individual do not result in a net subsidy.

To simplify notation, we define the amount of resources to be spent on \( c \) and \( \tilde{h} \) as \( X \). This is analogous to section A.1. The intra-temporal problem is then again given by the maximization of period utility \( u(c, \tilde{h}) \) given the constraint \( c + p^r \tilde{h} \leq X \).

**Homeowner Case:** In the absence of any deductions, the owner’s budget constraint can be written as follows, where \( T \) denotes the owner’s tax burden:

\[
c + s' + ph + AC + T = p^r(h - \tilde{h}) + (1 + r + mI_{(s<0)})s + (1 - \tau^{ss})y + p(1 - \delta)h_{-1} + Tr
\]

For the homeowner, the amount of resources available for consumption and housing services is thus given by:

\[
X = p^r h + (1 + r + mI_{(s<0)})s + (1 - \tau^{ss})y + p((1 - \delta)h_{-1} - h) - T + Tr - s' - AC
\]

In terms of the model’s solution, the only effect of the policy alternatives is to alter equation (21). The constraint becomes:

\[
c + p^r \tilde{h} - \Psi_1 \cdot (p^r - \delta p)\tilde{h} \tau^r \leq X - \Psi_2 \cdot rI_{(s<0)} s
\]

\[
c + p^r \tilde{h} (1 - \Psi_1 \cdot \hat{\tau}^r) \leq X - \Psi_2 \cdot rI_{(s<0)} s.
\]

The effective tax rate \( \hat{\tau}^r \) is given by \( \tau^r \cdot (1 - \delta \frac{p}{p^r}) \). By defining the amount of effective resources as \( \hat{X} \) and the effective price of housing services for the owner as \( \hat{p} \), we can use the exact same program to solve the intra-temporal problem for any combination of policy
alternatives.

\[ \dot{X} \equiv X - \Psi_2 \cdot r I_{\{s < 0\}} s \]
\[ \dot{p} \equiv p^r (1 - \Psi_1 \cdot \dot{r}) \]
\[ c + \dot{p} \tilde{h} \leq \dot{X} \]

**Renter Case:** The renter case can be derived analogously. For the renter, the amount of available resources is given by:

\[ X^r = Tr + (1 - \tau^ss)y + p ((1 - \delta)h_{-1}) - AC + (1 + r)s - s' - T \]

Note that the mortgage interest rate deduction can apply to a renter, as the renter can be a former homeowner who just sold her home and is paying off the mortgage in the current period. Following the same steps as above and noting that deduction 1 does not apply, we find that:

\[ \dot{X}^r \equiv X^r - \Psi_2 \cdot I_{\{s < 0\}} r s \]
\[ \dot{p}^r \equiv p^r \]
\[ c + \dot{p}^r \tilde{h} \leq \dot{X} \]

**A.3 Voluntary Savings**

In the numerical solution, we follow Yao and Zhang (2005) who define voluntary savings instead of actual savings. In equation (8), the lower bound on savings, which is equivalent to the maximum mortgage the household can hold, depends on the value of the house and is thus time-varying. Instead, we can define voluntary savings as:

\[ b' = s' + (1 - d)h p \]

so that whenever \( b' \) is set equal to zero, the household holds the maximum mortgage allowed, \( (1 - d)h p \). This formulation has the advantage of creating a rectangular constraint set with \( c, b' \) and \( h \) bounded below by zero. This makes the computational solution on a grid significantly easier. It comes at the cost of having to carry the previous period’s price as an additional state. A further downside of this formulation is that it implies that mortgages involve margin calls and that negative home-equity is not allowed.
State Space and Choice Variables: Before describing our solution algorithm in more detail, it will be useful to define the state space and control variables. A household’s current state depends on four variables: the housing stock $h_{t-1}$ and savings $s$ at the beginning of the period, the current realization of the persistent, idiosyncratic income shock $\eta$ and the household’s age $j$. A household chooses whether to rent or buy, and in the latter case how many housing units $h$ to purchase. Other choice variables are savings $s'$ and the amount of housing services consumed in the current period $\tilde{h}$.

The housing variable $h$ can take a value of zero if the household decides to rent, and a value in the set $\{h_{\text{min}}, h_{\text{min}}(1-\delta)^{-1}, h_{\text{min}}(1-\delta)^{-2}, \ldots\}$ if the household decides to be a homeowner. Restricting the housing choice to the delta-spaced housing grid is a convenient assumption in the presence of fixed transaction costs. In section A.3 we introduced the concept of voluntary savings $b = s + (1 - d)h_{t-1}p_{t-1}$. This reformulation of the model allows us to work with a rectangular constraint set as the lower bound on choices of $b$ is always zero and thus independent of the housing choice. We approximate the state variable $b$ with a grid. Using the parameters of the estimated autoregressive income process described in section 6.1, we use a procedure introduced by Tauchen and Hussey (1991) to discretize the income process with an eight-state Markov process. As outlined in the calibration section 6, the model contains nine working cohorts and a group of retirees. Dying agents are replaced with an equal measure of newborn agents and we normalize the total measure of households to one. The relative size of the cohorts can thus be derived from the retirees’ survival probability.

**Calculation of Stationary Equilibria:** Stationary equilibria are calculated for a given policy regime and constant prices and rents. We start with a reasonable guess of the level of lump sum transfers. Given those transfers and prices, we calculate optimal policies by solving an infinite horizon problem for retirees using value function iteration. We use the resulting value function to solve the working cohorts’ problem backwards. Using the optimal policy correspondence, we simulate the economy forward until a stationary distribution of agents over the state space is achieved. We then check market clearing in the housing and rental market. The equilibrium prices are found using the nonlinear optimization routine `fminsearchcon` in Matlab. In a last step, we adjust the level of transfers and iterate until the government budget constraint clears as well.

To simplify the problem, we first calculate the amount of resources available for consumption of the nondurable good and housing services for all combinations of states and remaining controls. That allows us to solve a simple static optimization problem as outlined
in section A.1. Here, it is important to carefully consider corner solutions. Using the optimal allocation of resources to those two uses, we calculate the momentary utility flow for all possible choices and store those in a large multidimensional object. The actual iteration on the value function is then simple and fast. To further improve computational speed, we vectorize the problem such that there is only a single maximization per iteration.

In the simulation, we store the exact distribution on the state space grid. This allows for a fast simulation routine given the Markov properties of both the exogenous processes and the policy correspondences.

**Solution Algorithm for Transitions:** For a given set of parameters and policy variables, define the vector of market clearing equilibrium prices and government transfers as \( q_t \). Here, this vector has three elements: \( p_t, p'_{t} \) and \( Tr_t \). Recall that \( \Omega_t \) captures the distribution of agents over age, income, owned housing and savings.

First, we have to guess the approximate length of the transition phase, \( T \). Choosing a higher number is computationally intensive, but ensures that transition can be achieved within the number of periods considered. If transition can be achieved in a smaller number of periods, the last transition periods will already look very similar to the new steady state. In our simulations we choose a conservative \( T = 25 \), but find that the transition path is not affected significantly for values of \( T \) greater than 15. After solving for the stationary equilibria before and after the policy change that we are interested in, we know the starting points \( q_0 \) and \( \Omega_0 \) as well as the end points \( q_T \) and \( \Omega_T \). The algorithm can now be described as follows:

1. Guess a sequence of \( \tilde{q}_t \) for \( t = 1, ..., T - 1 \).
2. Solve backwards for the value functions given the guessed values \( \tilde{q}_t \). For example, for period \( T - 1 \), we can easily calculate \( V_{T-1} = \max u_{T-1} + \beta V_T \) given \( \tilde{q}_{T-1} \) as \( V_T \) is known in the news stationary equilibrium. Ignore distributions, since we are not yet interested in market clearing.
3. Now solve forward: For period 1, find the market clearing \( \bar{q}_1 \), given \( V_2 \) calculated in step 2 and \( \Omega_0 \). Also calculate \( \bar{\Omega}_1 \). This gives the sequence of \( \bar{q}_t \) and \( \bar{\Omega}_t \) for \( t = 1, ..., T - 1 \).
4. Compare \( \tilde{q}_t \) and \( \bar{q}_t \). If not the same, replace \( \tilde{q}_t \) by a weighted average of \( \tilde{q}_t \) and \( \bar{q}_t \) and return to step 2.
5. Compare \( \bar{\Omega}_T \) with \( \Omega_T \) and increase \( T \) if the two distributions differ.