ABSTRACT

Title of dissertation: ESSAYS ON HOUSING MARKET AND WEALTH INEQUALITY

Hyung Suk Choi
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Dissertation directed by: Professor S. Borağan Aruoba
Professor John Shea
Department of Economics

I describe two studies on housing market and wealth inequality. In Chapter 1, I study the impact of changes in U.S. housing policy - down payment requirements and the mortgage interest deduction - on the wealth distribution through transitions in housing tenure and asset allocation. I build a simple three-period overlapping generations model that features endogenous rental supply and voluntary bequests, and analyze its steady state. I show how down payment requirements can affect the housing market and the wealth distribution: for example, if the down payment ratio falls from 0.2 to 0.1, the homeownership rate increases by 5.6% and the wealth Gini index decreases. In an alternative experiment, when only owner-occupiers are allowed to borrow using a lowered down payment ratio, the effects on the housing market and wealth distribution become smaller, with less distortion in the rental market. Finally, when the home mortgage interest deduction is repealed, housing demand drops and wealth inequality increases, as only wealthy households can become homeowners.

Chapter 2 studies the impact of a unique property tax scheme in South Korea on the housing market and wealth inequality. A recent change to Korea's property tax levies a heavy property tax on multiple home owners. The policy objective is to decrease wealth inequality by penalizing wealthy homeowners who own multiple houses. I build an eight period dynamic lifecycle model with a housing tenure choice to study the distributional effects of the Korean property tax scheme. I conduct a counterfactual experiment which discriminates among homeowners by their units of owned housing with two different property tax rates and compare outcomes to the benchmark economy. While the alternative property tax scheme actually decreases wealth inequality, the magnitude of the effect is very small.

ESSAYS ON HOUSING MARKET AND WEALTH INEQUALITY

by

Hyung Suk Choi

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Advisory Committee:
Professor John Shea, Chair / Co-Advisor
Professor S. Borağan Aruoba, Co-Advisor
Professor Luminita Stevens
Professor Thomas Drechsel
Professor Liu Yang

Dedication

To Woojae and Kyung Jin

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Chapter 1: Housing Policy and Wealth Inequality

1.1 Introduction

As a necessity good, housing takes a large portion of the household portfolio and consumption basket. On average, 18% of household consumption expenditure is allocated to housing services in the U.S. (National Income and Product Account 1954–2016), and housing wealth is the largest asset in homeowners' collective balance sheet. The recent Great Recession further demonstrates how disruptions in the housing market can impact the U.S. economy. Despite its importance, not every household can fully enjoy the benefits of housing, as many households live in rental units.[1] The homeownership rate in the U.S. exhibited a pronounced boom and bust in the recent crisis, peaking at near 70%, but historically has stayed just over 60% since the 1970s. This means that roughly 40% of households are renters, either voluntarily or involuntarily. In fact, many households, mostly the young, cannot afford a down payment on a house for various reasons, such as low labor income, insufficient credit, or low liquid wealth, and remain as renters. This paper is motivated by the observation that many of these involuntary renters may lag be-

[1] The property of housing as a consumption good and as investment asset is often referred to as the dual role of housing. When mortgage financing is also counted as a benefit of housing, housing is said to have a triple role.

hind in wealth accumulation, since the lost (or delayed) chance to own a home can widen the wealth gap between homeowners and renters.[2] In this Chapter, I explore a simple economy where households can choose their housing tenure with no capital returns from housing and illustrate how the housing market and wealth distribution interact in steady state.

There is a long literature that studies various aspects of the housing market. Some studies focus on the effect of housing price shocks on consumption and welfare as in Campbell and Cocco [2007], while others conversely examine the source of shocks causing the recent housing market boom and bust (Kaplan et al. 2015 among others). However, there is little research studying how wealth inequality is affected by the housing market.[3] Since the dynamic role of housing markets in generating wealth inequality has not yet been fully explored in the literature, specifying the mechanism and quantifying its impact is worthwhile.

The central question I ask in the paper is how changes to current U.S. housing policies would alter household access to homeownership and affect the wealth distribution. To study this question quantitatively, I build a parsimonious three-period overlapping generations model in which households face uninsurable idiosyncratic earnings risk. Households have three tenure choices: They can be landlords, owner-occupiers or renters. As landlords are the sole suppliers of rental units, changes in housing tenure affect both housing and rental markets. Households consume and save in risk-free financial assets (deposits) each period. Households can access home

[2] Kiyotaki et al. [2011] and Sommer et al. [2013] point out that the down payment requirement is a hurdle to becoming a homeowner.

[3] Zhang [2015] is the only paper that explicitly studies this issue, but he explores the effect of income inequality on house prices, not the impact of housing on wealth inequality as in this study.

equity (mortgage) loans, at the cost of a down payment constraint which must be satisfied whenever they adjust their mortgage debt or change housing stock. Young households can benefit from inheritance and can leave bequests later in their lives, but notably they cannot receive inheritances at the beginning of their economic lives: i.e. all households start with zero financial assets.[4] Specifically, I follow De Nardi [2004] and De Nardi and Yang [2016] and assume "warm glow" bequests.

First, I employ the model to analyze potential effects of changes to down payment requirements. By comparing each alternative steady state with a baseline economy calibrated to long-run U.S. data moments, I find the following results. First, changes to the down payment ratio affect the housing market. As the down payment requirement varies from 0.4 to 0.1, the homeownership rate rises from 60.2% to 69.7% and the landlord rate increases from 6.9% to 7.3%. Second, the down-payment requirement mildly affects the wealth distribution of the U.S. As the down payment requirement varies from 0.4 to 0.1, the wealth Gini index decreases from 0.697 to 0.685. Also, when compared with the average Gini index estimated from Survey of Consumer Finances (SCF), a fall in the down payment ratio from 0.2 to 0.1 makes the Gini index decrease from 0.687 to 0.685. To further understand the changes in housing tenure choices, I explore counterfactual intermediate stages that lie between the two steady state equilibria and analyze the general equilibrium effects step by step.

Second, I study an alternative policy to allow a lower down payment ratio

[4] In my view, this is not a strong assumption in that most households inherit at middle-age, and an aging population can be another factor that postpones bequests.

only for owner-occupiers. By comparing two economies, one adopting this dual down payment ratio policy (a down payment ratio of 0.2 for landlords and 0.1 for owner-occupiers) and the other adopting a relaxed down payment policy for everyone (a downpayment ratio of 0.1), I find out that the expected distortion in the rental market is muted by a fall in rental demand. Also, the effects on housing tenure and the wealth distribution are smaller when relaxed downpayment ratios are only available to owner-occupiers.

Lastly, I study the effect of repealing the mortgage interest deduction. Changing the income tax code to repeal this deduction has been discussed for a long time for reasons such as the need for adjusting excessive favors given to homeowners or large losses in U.S. governement tax revenue. In my model, when the mortgage interest deduction is repealed, housing demand drops with a fall in housing price. The homeownership rate falls as more wealth is required for homeowners to support the additional costs. Wealth inequality worsens as access to home ownership gets more expensive. Thus, good intentions could lead to bad outcomes in this case.

In a nutshell, this paper shows that the effect of housing policy is not limited to the housing market, but rather extends to the wealth distribution. The distributional impact of housing policy has been ignored in much previous work. In this regard, I underline the idea that careful and thorough policy assessment, including distributional impacts, in a general equilibrium framework, is important when considering new policy, lest policy changes lead to disappointing or unexpected outcomes.

The rest of the paper proceeds as follows. Section 1.2 overviews the literature to which this paper contributes. Section 1.3 outlines the overlapping generation model, Section 1.4 defines the steady-state competitive equilibrium, and Section 1.5 discusses the calibration of the model. Section 1.6 discusses baseline quantitative results, Section 1.6, 1.7 and 1.8 study each policy experiment and Section 1.9 concludes.

1.2 Previous Literature

This paper relates to two strands of literature. The first literature develops models with uninsurable earnings risk, represented by Aiyagari [1994] and Huggett [1996], who adapted the model to an overlapping generations environment. The literature broadly studies topics of wealth inequality and tries to match the skewed wealth distribution with additional model features besides earnings shocks.

Various underlying factors affecting wealth inequality have been studied in the literature, including bequest motives and human capital (De Nardi 2004, De Nardi and Yang 2016), heterogeneous preferences (Krusell and Smith 1998), and entrepreneurs (Cagetti 2006) among other factors. More potential factors, such as health-related expenditure, increasingly have been added to the literature. This paper adds to the literature by introducing the idea that heterogeneity in earnings and bequests, which are already highly concentrated among the wealthiest few, can be further amplified through housing markets to make wealth concentration in the economy even higher.

Second, this paper contributes to the literature on housing markets and their role in the economy. The main objective of the paper differs from previous works, which focus mainly on the effect of house prices on macro variables (Kiyotaki et al. 2011, Sommer et al. 2013, Favilukis et al. 2017), or on the sources of house price booms and busts. This paper reverses the direction of research interest in that housing markets can work as a channel that affects wealth inequality. The paper is also related to empirical findings on the effect of borrowing constraints on homeownership. Notably, Acolin et al. [2016] finds that wealth, income and credit are three main constraints that limit access to mortgages, so that households with insufficient wealth, income and/or credit are precluded from owning a house and making an optimal tenure choice. Haurin et al. [1996] also supports the significance of homeownership in wealth accumulation, especially in the year before and the first year of homeownership.

In terms of modeling the rental market, the literature exhibits two distinct frameworks. Gervais [2002], Kiyotaki et al. [2011] and Yang [2009] assume a financial intermediary that supplies rental properties. Alternatively Chambers et al. [2009a] and Sommer et al. [2013] assume that households own rental properties and rent to other households as an investment strategy. I follow the latter framework to incorporate housing price and rental price variables explicitly in the model.[5]

[5] The literature belonging to the first framework assumes that the housing price is equal to the price of consumption (Sommer et al. 2013).

1.3 Model

I build a dynamic overlapping-generations general equilibrium model that features a voluntary bequest motive and housing tenure choice. The basic structure of the model is based on Aiyagari [1994] with the following features added. One is the structure of the housing and rental markets, taken from Sommer et al. [2013] and Chambers et al. [2009a], in which an agent can be a renter, an owner-occupier, or a landlord who directly supplies rental units to other agents.[6] This model feature is different from the literature that assumes a financial intermediary which purchases housing stock from the market and supplies to renters. The other is a bequest function taken from De Nardi [2004] and De Nardi and Yang [2016], who focus on the role of bequest motives in wealth transfers across generations. In my model, agents derive utility from non-durable consumption and rental (or housing) services, which can be obtained either from renting or through ownership. Agents receive uninsurable earnings shocks and supply labor inelastically. They save in risk-free financial assets (deposits) and can use their housing as mortgage collateral to borrow from a financial intermediary.

1.3.1 Demographics

I assume an agent lives for three periods. At $t = 1$, the agent enters the economy with zero assets, and her productivity is inherited stochastically from parents

[6] Chambers et al. [2009a] supports the model structure by documenting that the majority of U.S. rental property is owned by households.

(human capital transfer). At the end of that period, the agent inherits her parents' wealth. At period $t = 2$, the agent works with a new level of productivity due to idiosyncratic shocks. At $t = 3$, the agent retires, receives a pension and leaves a bequest to her sole child at the end of the period (see Figure 1.2). Population is constant and thus each period the number of agents entering the economy is the same as the number of deceased agents.

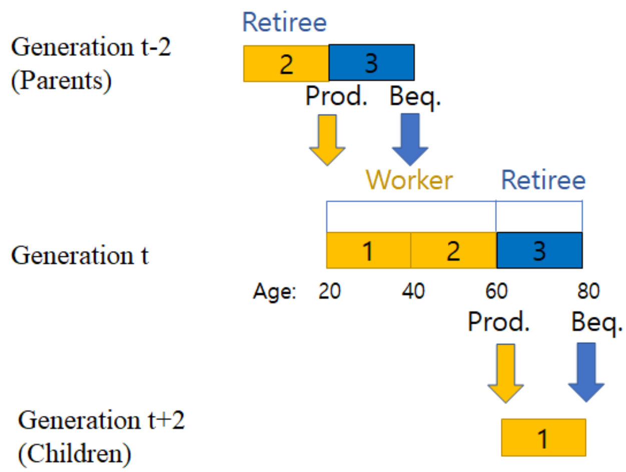


Figure 1.1: Description of Demographics

1.3.2 Labor Earnings Process

The total labor productivity for an agent i is the product of two mutually exclusive processes: a deterministic age-efficiency profile ε_t and productivity shocks z_t^i: i.e. $e^{z_t^i+\varepsilon_t}$. The age-efficiency profile ε_t, which is commonly applied to every agent, follows Hansen [1993]. The idiosyncratic component z_t^i, on the other hand, follows an AR(1) process as $z_t^i = \rho_z z_{t-1}^i + \mu_t^i, \mu_t^i \sim N(0, \sigma_z^2)$. In sum, labor earnings for the agent i are $y_t^i = we^{z_t^i+\varepsilon_t}$, where w is the wage level. Similarly, children j inherit their productivity level stochastically from their parent i in period $t = 1$, when their parents are in period $t = 3$, i.e. $z_1^j = \rho_h z_2^i + \upsilon^j,\ \upsilon^j \sim N(0,\, \sigma_h^2)$.

1.3.3 Preferences

Utility from Consumption goods The agent consumes nondurable goods and services c and housing services s, and achieves the following flow utility:

$$U(c, s) = \frac{(c^{\eta} s^{1-\eta})^{1-\gamma}}{1-\gamma} \tag{1.1}$$

where η is the expenditure share of nondurable goods and services in total expenditure, and γ is the relative risk-aversion parameter.

Utility from Bequests I assume that the agent leaves voluntary bequests in the last period ($t = 3$). The bequest utility function follows De Nardi [2004] and De Nardi and Yang [2016], and is denoted by

$$\phi(b) = \phi_1[(b + \phi_2)^{1-\gamma} - 1], \tag{1.2}$$

where ϕ_1 controls the strength of bequest motives by affecting the marginal utility from bequests, and utility shifter ϕ_2 governs the extent to which bequests are luxury goods.[7] Since the agent derives utility from bequests, she maintains a portion of her wealth even later in her life.[8]

[7] If $\phi_2 > 0$, the marginal utility of small bequests is bounded, while the marginal utility of large bequests declines more slowly than the marginal utility of consumption (De Nardi and Yang 2016). This makes bequests a luxury good. I discuss these parameters more in Appendix *A.2*.

[8] This is how bequests can help match the high saving rates of old households.

Tenure Choice Housing services can be obtained either via rental units at price ρ or through home ownership at price q per unit of housing stock. I assume a linear technology that allows transformation from housing stock into housing services one to one following Sommer et al. [2013]. The household can be a landlord ($h' > s$), an owner-occupier($h' = s > 0$), or a renter ($h' = 0$).[9, 10]

1.3.4 Assets and Market Arrangements

Assets and Home Equity Loans Agents can accumulate wealth using two assets: housing stock (or residential assets, interchangeably: $h' \geq 0$) and deposits (or financial assets, interchangeably: $d' \geq 0$) earning a constant risk-free interest rate r. If agents own housing, they can borrow using long-term home equity loans (or mortgage debt, interchangeably: $m' \geq 0$) with a constant interest rate r^m. I assume $r^m = r + \iota$, where ι is a spread over the risk-free interest rate.[11] At the beginning of each period, agents have stocks of h, d, and m carried over from the previous period. After earnings shocks are revealed, agents choose h', d', and m'. Note that agents begin with zero financial assets and housing stock in the first period and cannot hold mortgage debt at the end of the last period. Timing is different for the housing

[9]Note that in this paper, households get the same amount of utility per unit of housing regardless of tenure. By contrast, [Kiyotaki et al., 2011] assumes lower utility from rental residences, and [Sommer et al., 2013] assumes landlords lose some utility due to managing a rental property.

[10]In practice, a household can live in a rental unit while owning a house somewhere else. This so-called "owner-renter" is usually omitted from the analysis in the literature. I experimented with allowing this type of household in my model, but found that households optimally choose not to become "owner-renters". Therefore, I follow the literature and ignore this type of household in this paper.

[11]Many models in the housing market literature assume a constant rate of return for financial assets and a higher interest rate for mortgage debt (see Díaz and Luengo-Prado 2008, Díaz and Luengo-Prado 2011, and Sommer et al. 2013 among others). Notably, [Chambers et al., 2009b] assumes that the anticipated inflation rate equals the spread over the real interest rate. More details will be discussed in the discussion of the financial intermediary.

stock in that h' denotes the stock used in the current period, and I assume that all relevant costs and tax payments are related to homeownership, following Chambers et al. [2009c], Sommer et al. [2013], and Sommer and Sullivan [2018]. Housing stock is available in discrete sizes as $h' \in \{0, h(1), ..., h(Q)\} \equiv \mathbb{S}_H$, where index Q is a constant representing the maximum size of a house and $\mathbb{S}_H$ a set of possible house sizes. Renters can choose all house sizes in $\mathbb{S}_H$ as well as an even smaller size unit of shelter from a set of possible shelter sizes $\mathbb{S}_S$ as $\underline{s}$: $s \in \{\underline{s}, h(1), ..., h(Q)\}$, where $0 < \underline{s} < h(1)$.

Various Costs Households pay transaction costs when purchasing ($\kappa^p q h'$) or selling ($\kappa^s q h$) housing stock. The cost for selling is greater than the cost for purchasing, i.e. $\kappa^s > \kappa^p$, which creates a non-convexity in the model. These costs represent opportunity costs such as the amount of time spent on market search, brokerage and agent fees, moving costs, and so on (Yang 2009). Non-convex transaction costs allow for lumpiness and inaction regions in housing choices, and reflect practical considerations in purchasing or selling houses. Homeowners pay maintenance costs at the depreciation rate of δ_h. The maintenance cost function can be described as $M(h') = q \cdot \delta_h h'$. Lastly, landlords in the model have to pay a fixed cost of ω, following Sommer and Sullivan [2018], which represents actual costs related to being landlords.

Financial Intermediary A financial institution functions as an intermediary to channel financial (or nonresidential) capital K from households to the firm at the risk-free interest rate r. Financial capital can be transformed one to one from deposits D, made by households through saving. The institution also makes home equity loans M to agents at rate r^m. The financial institution is risk-neutral, pools all the financial assets and earns no profit in equilibrium.

I make two assumptions about transactions of financial assets. One is that home equity loans, or mortgage loans, are subject to financial regulations, represented by a down payment ratio θ. In practice, home equity loans are determined by an individual's financial status, such as income (*Debt-to-Income* ratios) or the total value of the house (*Loan-to-Value* ratios). A down payment requirement is not sufficient to capture the variety of regulations in the U.S., but it is a good simplifying assumption often made in the literature. The second assumption is that the loan rate r^m is a fixed spread ι over the risk-free interest rate r in the model (see Figure 1.2 for evidence on such spreads for the U.S. since 1977). If there is no friction in the financial sector, the equilibrium level of mortgage interest rates should be equal to the risk-free rate, since otherwise the financial institution will easily substitute from lending to financial capital borrowers (firms) to home equity borrowers (agents) to earn more. I thus interpret ι as transaction costs associated with mortgage lending, which in turn equalize the marginal returns from lending in financial capital K and home equity loans M.

Since the intermediary represents the supply side of nonresidential capital and mortgage loans, and the demand side of deposits, its balance sheet (see Table 1.1) is another description of the financial market. In the following, I use the term "asset market" to refer to all three financial asset categories, and consequently the intermediary's balance sheet being balanced will be used as an equilibrium condition. I postpone the details to Section 5.[12]

Asset	Liability
Mortgage Loans (M) Loans to Firms (K)	Deposits (D)

Table 1.1: Balance Sheet of Financial Intermediary

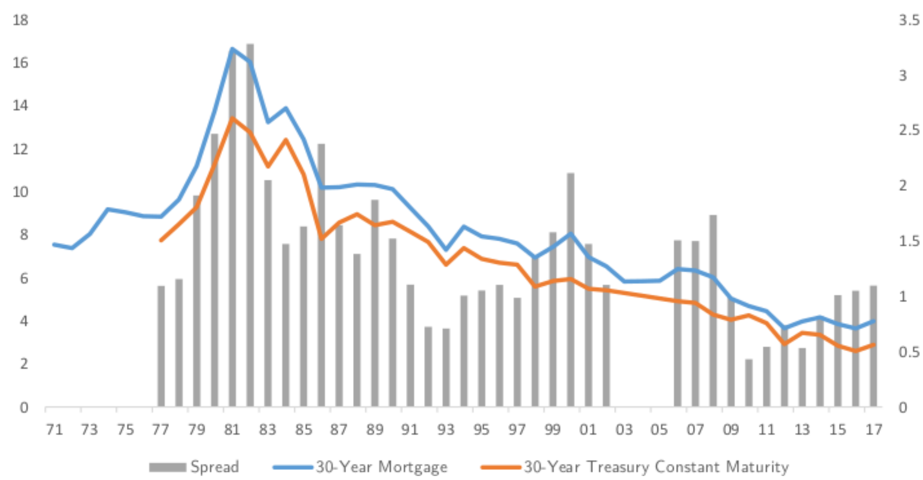


Figure 1.2: Mortgage Interest Rate and Treasury Yield

1.3.5 Final Good Firm and Technology

A representative firm produces final goods with constant returns to scale technology $F(K, L) = K^{\alpha}L^{1-\alpha}$, where K and L denote financial capital and labor demand.[13] The factor markets are competitive and thus capital and labor income have constant shares. The final goods can be consumed and invested in physical capital with depreciation rate δ.

[12]The financial sector follows Chambers et al. [2009a] and differs from the literature that assumes that the financial intermediary buys housing stock and rents units in the market (Gervais 2002, Díaz and Luengo-Prado 2010, for example). Note that, however, in those papers, the price of housing stock is the same as the price of consumption goods.

[13]I denote $F_K(K, L)$ and $F_L(K, L)$ as the marginal products of capital and labor.

1.3.6 Government

Tax and Deductions The tax system consists of a general income tax at rate τ^y, an estate tax at rate τ^b, and a property tax on houses at rate τ^h. Notably, there are a variety of preferential tax deductions for homeowners, following Díaz and Luengo-Prado [2008]. First, the benchmark model assumes a full deduction for property taxes on housing stock h' from taxable income, denoting the value of this deduction as $\tau^h qh'$. Second, there is a deduction for mortgage debt interest payments from taxable income, denoted as $\tau^m r^m m$, where τ^m is the deduction rate and r^m the mortgage interest rate. Lastly, the model has separate deductions for landlords, whose taxable income includes rental income, but who can deduct a fraction of the maintenance costs paid for rental units and the depreciated value of tenant-occupied houses with deduction rate τ^{ll}, as in the U.S. tax code. These deductions are major incentives that favor homeownership in the U.S. The remaining taxes are all levied proportionally, although the estate tax levies a rate of τ^b on the agent's bequests net of an exemption level x_b, which allows some portion of the bequest to remain untaxed.

Social Security Social security benefits are modeled in a simple manner, to focus on the housing market, and to avoid further aggravating the curse of dimensionality. The government distributes a lump-sum pension tr each period to retired agents, and funds the expenditure from income tax revenue. All remaining tax revenues are used for government consumption expenditure G, which does not affect an individual agent's decision.

1.3.7 Dynamic Programming Problem

In this section, I specify the model economy with properties as discussed above. First, I divide the life-cycle of agents (or households) into three periods. The young and middle-aged generations work and earn labor income, and the old generation consists of retired agents who receive social security benefits and leave some of their assets to the next generation. The age difference between generations equals two model periods, and thus agents in the model inherit bequests at the end of the first period (just before transition to being the middle-aged generation). Consequently, three value functions appear in the model: one for the young generation (V_w), another for the middle generation (V_m), and the other for the retired agents (V_r).

1.3.7.1 Young Generation

A young agent starts in period $t = 1$ with no financial or housing assets. She earns labor income, accumulates assets, purchases or rents housing, and can borrow against her owned housing. The agent expects to receive bequests at the end of the period, since their retired parents die with probability one. The young agents can be represented by the following recursive dynamic problem. S_p is a collection of the parent's state variables, defined as $S_p = (d_p, m_p, h_p)$.[14]

[14]Note that state variables of the parents cannot be reduced to a single net wealth variable. Two parents with the same wealth level but different composition of assets at the beginning of the period make different choices because of income taxes, transaction costs, mortgage debt and so on.

$$V_w(S_p, z) = \max_{c,s,d',m',h'} U(c,\, s) + \beta E[V_m(d' + b_n,\, m',\, h',\, z')] \tag{1.3}$$

subject to:

$$c + \rho(s - h') + I^{h'\neq 0}\kappa^p qh' + I^{h'\neq 0}M(h', s) + I^{h'>s}\omega$$

$$\leq y - d' + m' - qh' - \left[\tau^y \tilde{y} + \tau^h qh'\right] \tag{1.4}$$

$$\tilde{y} = y - \tau^h qh' + I^{h'>s}\left[\rho(h' - s) - \tau^{ll}q(h' - s) - \delta_h q(h' - s)\right] \tag{1.5}$$

$$M(h') = \delta_h \cdot q \cdot h' \tag{1.6}$$

$$m' I^{\{(m'>m)\cup(h'\neq h)\}} \leq (1 - \theta)qh' \tag{1.7}$$

$$m' \geq 0 \text{ and } d' \geq 0 \tag{1.8}$$

$$h' \geq s \quad \text{if } h' > 0 \tag{1.9}$$

$$b_n = b(S_p) \tag{1.10}$$

State Variables The state vector for the young generation consists of their realized productivity level (z) and the parent's state variables (S_p), which in turn consist of the parent's deposits (d_p), mortgage debt (m_p) and housing (h_p). Agents' productivity level is inherited from their parents (recall section 1.3.2). Since the young enter the economy with no positive assets but may hold assets at the end of the period, only parents' asset variables appear in the value function for the young generation. The prime superscript denotes next period variables: for example, mortgage debt m is the choice from the previous period, and m' is this period's choice. Note that state variables of parents affect the value function of the young because they affect bequests made at the end of the period, and the net bequests are added to the next period deposits (d') of the children.

Expenditure The agent spends on nondurable goods and services c, saves in risk-free deposits d', and pays housing transaction costs. Transaction costs are at rate κ^s when selling and at rate κ^p when purchasing.[15] The indicator function I throughout the paper equals one when the conditions in the superscript are satisfied: for example, $I^{h'\neq 0}$ is one when agents are homeowners, $I^{h'>s}$ is one when agents are landlords, $I^{h'<h}$ is one when agents sell housing, and $I^{h'>h}$ is one when agents are net purchasers of housing. Note that renters and homeowners who do not change house size pay no transaction costs. Homeowners pay maintenance costs $M(h')$ that vary with house value.

Incomes The working agent earns labor income y, and residential rental income for landlords $\rho(h'-s)$.[16] Government levies an income tax on labor income and (for landlords) rental income, net of deductions allowed for homeowners, and as specified in Section 1.3.6, additional deductions allowed for rental units owned by landlords. The agent further pays housing property tax at rate τ^h. Young agents inherit wealth net of bequest tax from their parents, but this does not appear in the

[15] It is evident that if $m' = m$, and if the agent maintains the same housing stock, the agent only makes the mortgage interest payment each period. Furthermore, when a homeowner purchases a new house, she needs to pay both transaction costs.

[16] Recall that labor earnings $y = we^{z+\varepsilon}$.

agent's first-period budget constraint since death occurs at the end of the period. Notably, children inherit net bequests b_n, which will be discussed when studying the problem of the old generation in Section 1.3.7.3. Eq.(1.11) summarizes the composition of taxable income for working agents.

$$\begin{aligned}
&\text{Taxable Income} \\
&= \text{Labor Income} + \text{Interest Earnings} + I^{\text{Landlord}} \cdot \text{Rental Income} \\
&- I^{\text{Owner}} \cdot (\text{Mortgage Interest} + \text{Property Tax}) \\
&- I^{\text{Landlord}} \cdot (\text{Rental Depreciation} + \text{Rental Maintenance}) \qquad (1.11)
\end{aligned}$$

Housing Service The agent pays or receives rent at price ρ depending on housing consumption s and housing stock h'. For example, if the agent is a renter, i.e. $h' = 0$, she pays the amount ρs to the landlord. On the other hand, a landlord agent, i.e. $h' > s$, does not pay for her own housing service consumption and further receives rental payment $\rho(h' - s)$ from the renter. If the agent becomes a homeowner or moves to a bigger house, she needs to pay price q per unit of housing stock. This structure differs from the strand of the literature that assumes that financial intermediaries purchase the housing stock and provide housing rental services (Gervais 2002, Díaz and Luengo-Prado 2010, for example). A major drawback in those models is that one cannot study movements of housing prices relative to consumption goods since this price is fixed at one. Chambers et al. [2009a] provides the basis of the framework used here, and they stress that the majority of U.S. rental property is owned by households, which supports modeling the supply side of housing services as being provided by other agents.

Down payment Eq.(1.7) describes the down payment requirement. The requirement states that the agent must possess at least $\theta q h'$ of wealth to purchase a house. There is no default in the model and thus the agent can maintain mortgage debt unless the agent changes her housing stock, and thus one can treat mortgage debt as a long maturity asset. As noted, the housing stock works as collateral to borrow from the financial intermediary.[17]

1.3.7.2 Middle Generation

Agents at period $t = 2$ solve the following recursive problem

$$V_m(d, m, h, z) = \max_{c,s,d',m',h'} U(c,\, s) + \beta E[V_r(d',\, m',\, h')] \tag{1.12}$$

subject to:

$$\begin{aligned} & c + \rho(s - h') + \left[I^{h'<h}\kappa^s q h + I^{h'>h}\kappa^p q h'\right] + I^{h'\neq 0}M(h') + I^{h'>s}\omega \\ & \leq y - [d' - (1+r)\cdot d] + [m' - (1+r^m)m] + q(h-h') - \left[\tau^y \tilde{y} + \tau^h q h'\right] \qquad (1.13) \\ & \tilde{y} = y + rd - \left[\tau^m r^m m + \tau^h q h'\right] + I^{h'>s}\left[\rho(h'-s) - \tau^{ll} q(h'-s) - \delta_h q(h'-s)\right], \qquad (1.14) \end{aligned}$$

and eq. (1.6) $\sim$ (1.9)

Note that from period $t = 2$, agents earn capital income from deposits rd

[17] Mortgage debt is the only source of borrowing in the model, i.e. renters cannot borrow.

and pay back (or roll over) mortgage loans m borrowed in the previous period with interest at rate r^m.

1.3.7.3 Old Generation

Old agents retire and receive social security benefits, and leave bequests to their children. They solve the following recursive problem:

$$V_r(d, m, h) = \max_{c,s,h',d'} [U(c, s) + \phi(b)] \tag{1.15}$$

subject to:

$$c + \rho(s - h') + \left[I^{h'<h}\kappa^s qh + I^{h'>h}\kappa^p qh'\right] + I^{h'\neq 0}M(h') + I^{h'>s}\omega$$

$$\leq tr - [d' - (1 + r) \cdot d] - (1 + r^m)m + q(h - h') - \left[\tau^y \tilde{y} + \tau^h qh'\right] \tag{1.16}$$

$$\tilde{y}_r = tr + rd - I^{h'\neq 0}\left[\tau^m r^m m + \tau^h qh'\right] + I^{h'>s}\left[\rho(h' - s) - \tau^{ll}q(h' - s) - \delta_h q(h' - s)\right] \tag{1.17}$$

$$\phi(b) = \phi_1[(b + \phi_2)^{1-\gamma} - 1] \tag{1.18}$$

$$b(d', h') = d' + (1 - \kappa^s)qh' - \tau^b \max(0, d' + (1 - \kappa^s)qh' - x_b), \tag{1.19}$$

and eq. (1.6) $\sim$ (1.9).

V_r denotes the value function for retired agents. Agents' state variables now shrink to deposits (d), mortgage debt (m), and housing stock (h). They die at the end of the period and leave bequests to their children. Equation (1.16) differs from Equation (1.4) in that instead of labor income, the old agent receives social security benefits, denoted by tr. Note that agents in this last period are no longer allowed to borrow, i.e. $m' = 0$.

Bequests The agents derive utility from leaving bequests according to function $\phi(b)$. Equation (1.19) indicates that the government levies estate taxes on the portion of net bequests beyond the exemption level x_b, where gross bequests are defined as the wealth of parents at the end of the period, and net bequests subtract housing selling expenses from gross bequests. The old generation anticipates their death and chooses bequests optimally. Note that, all else equal, deposits d' are more desirable as a bequest than housing stock h', since the latter incur selling costs.

1.4 Stationary Equilibrium

Definition of relevant variables To properly characterize a stationary equilibrium, let x be a state vector (z, d, m, h, S_p), $\mathcal{S}$ be the state space supporting x, and $\mathcal{B}_{\mathcal{S}}$ be the Borel σ-field. Aggregate variables are denoted with capital letters, e.g. C represents aggregate consumption, while I_K and I_H denote aggregate investment in nonresidential capital and housing stock.[18] Further note that H denotes aggregate demand for housing stock, H^s denotes aggregate housing supply, which is fixed in this paper, and PENS denotes aggregate pension expenditure.

Competitive Stationary Equilibrium A Competitive Stationary Equilibrium is defined as a collection of value functions, prices, individual policy functions, ag-

[18] Aggregate investments are defined as follows: $I_K \equiv \delta K$, $I_H \equiv \delta_h q H$. Note that aggregate variables are constant at the steady state.

gregate allocations, government policies, and a stationary distribution over x such that

1. Given prices, government policies, and the distribution of x, the agent optimally chooses $c(x)$, $s(x)$, $h'(x)$, $d'(x)$, and $m'(x)$.[19]

2. A representative firm maximizes its profit:

$$r = \frac{\partial F(K,\, L)}{\partial K} - \delta \tag{1.20}$$

$$w = \frac{\partial F(K,\, L)}{\partial L} \tag{1.21}$$

3. All markets clear:

   (a) The financial asset market clears:[20]

$$D = M + K \tag{1.22}$$

   (b) The housing market clears:

$$H = H^s, \tag{1.23}$$

[19] Agents are atomistic so that each individual does not consider other agents' decisions explicitly.

[20] Formally, the deposit market, mortgage market, and capital market should all independently clear in equilibrium as follows:

$$D = \int_S d'(x)\,\mathrm{d}\lambda,\;\; M = \int_S m'(x)\,\mathrm{d}\lambda,\;\; \text{and}\, K^s = K,$$

where D is demand for deposits by the financial firms, M is provision of mortgage loans by the financial firms, and K^s is capital supply by the financial firms. However, the financial intermediary is involved in all financial asset transactions, and the balance of the intermediary's financial statement can be described as an asset market equilibrium condition. This is because all the financial assets are convertible one to one and they are treated like an single asset in the model (i.e. the counterpart of deposits (supply of financial assets) is demand for mortgage loans and capital).

(c) The rental market clears:

$$S = H^s \tag{1.24}$$

(d) The government budget is balanced:[21]

$$G + \text{PENS} = T \tag{1.25}$$

(e) The goods market clears:

$$C + I_K + I_H + G + \Gamma = Y \tag{1.26}$$

where Γ denotes aggregate transaction costs.[22]

1.5 Quantitative Analysis

1.5.1 Solution Algorithm

The non-convex transaction costs in the model preclude me from using an Euler equation approximation that requires differentiability (Díaz and Luengo-Prado 2008). Instead, I approximate value functions with discretized finite grids. Follow-

[21] Aggregate government tax revenue T is the sum of revenues from the income tax, (housing) property tax and bequest tax, net of aggregate deductions: i.e.

$$\begin{aligned} T = & \tau^y \left(Y - \delta K + PENS + \rho S_R - \tau^h qH - \tau^m rM - (\tau^{ll} + \delta_h) \cdot q \int_{LL} (h'(x) - s(x)) \, \mathrm{d}\lambda \right) \\ & + \tau^h qH + \tau^b \int_{LL} (b(x) - x_b) \, d\lambda(x), \end{aligned}$$

where LL represents landlords.

[22] Aggregate transaction costs Γ are the sum of housing transaction costs, fixed costs to landlords and mortgage lending transaction costs: $\Gamma = \int_{Sell} \kappa^s qh(x) \, d\lambda(x) + \int_{Buy} \kappa^p qh'(x) \, d\lambda(x)$ $+ \int_{LL} \omega d\lambda(x) + \iota M$, where *Sell* and *Buy* represent selling households and purchasing households.

ing Díaz and Luengo-Prado [2008] and Sommer et al. [2013], I lump deposits and mortgages into a single measure of net financial wealth $a_t = d_t - m_t$.[23] This reduction of one state variable alleviates the computational burden, leaving net financial wealth, housing stock and productivity of the agent as state variables.[24] I solve for the optimal policy functions using backwards induction, compute the distribution of the model economy across the discrete state space and iterate until the distribution converges.[25] The following is the specific algorithm I use to compute the stationary equilibrium.

1. Make a i^{th} guess of the market clearing price vector: housing price q_i, rent price ρ_i, and interest rate r_i.

2. Search for price values such that excess demand of each market is close to zero. I use three nested loops to find equilibrium price levels for houses, rentals and financial assets.

    (a) In each iteration, find the optimal policy functions that solve the corresponding Bellman equations specified in Section 1.3.7 by backwards induction starting from $t = 3$.

    (b) With the policy functions from Step 2-(a), find the invariant distribution over the state space.

[23] Agents do not hold deposits and mortgages simultaneously when there is a spread in the interest rate between two assets (Díaz and Luengo-Prado [2008] prove this in their Appendix A.).

[24] To be clear, parents' three state variables are also state variables for young workers.

[25] I follow the literature and use a brute force discrete grid method. Since this method suffers from the curse of dimensionality problem, I write the program in generic-C and introduce parallel computing using OpenMP. I currently have 500 grid points for equity, 12 points for homeownership, and 12 points for housing service consumption. In comparison, Sommer and Sullivan [2018] used 7 points for the house grid.

3. With the policy functions and invariant distributions from Step 2, check if all markets clear. If satisfied, a stationary equilibrium is found. If not, go to Step 1, update the guess and repeat the $i+1^{th}$ iteration process.[26]

1.5.2 Calibration

Parameter		Value	Parameter		Value
Risk aversion	γ	2.5	Selling cost	κ^s	0.07
AR(1) coeff.(Inherit.)	ρ_h	0.400	Purchasing cost	κ^p	0.025
Innovation (Inherit.)	σ_h^2	0.370	Down-payment ratio	θ	0.2
AR(1) coeff.	ρ_z	0.920	Depreciation rate (K)	δ	0.1364
Innovation	σ_z^2	0.380	Capital share	α	0.3043(*)
Mortgage spread	ι	0.0124	Property tax rate	τ^h	0.01
Maintenace Cost	δ_h	0.015	Mortgage deduction	τ^m	1.0
Age-Efficiency Unit	ε_t	see text	Rental Depreciation rate	τ^{ll}	0.023

Note: (*) author's estimation using U.S. National Income and Product Accounts and Fixed Asset Tables 1954∼2016 data from the Bureau of Economic Analysis.

Table 1.2: Externally Calibrated Parameters

External Calibration I assume that population is constant and faces deterministic death at the end of the third period. One model period is 20 years and thus one can think of the young generation as being from age 20 to age 39, the middle generation as being from 40 to 59 and the old generation as being from age 60 to age 79. Each generation comprises one third of the whole population. I set the risk aversion coefficient $\gamma = 2.5$. I postpone discussion of the remaining preference parameters to the internal calibration process.

I follow Gruber and Martin [2003] and set the transaction cost for selling a house $\kappa^s = 7\%$, and the transaction cost for purchasing house $\kappa^p = 2.5\%$. I use the

[26] The government budget constraint is balanced with flexible government consumption expenditure and the goods market clears by Walras' law.

estimated value from Díaz and Luengo-Prado [2010] and set the annual maintenance cost parameter $\delta_h = 0.015$.[27] Next, in the benchmark model, I set the down-payment ratio $\theta = 20\%$ as is standard in the literature (Gervais 2002, for example). θ is a key parameter in the paper and I use it to conduct a policy experiment in Section 6.

I use the 30-year fixed-rate mortgage interest rate as a proxy for the interest rate on home equity loans, and proxy the risk free rate using the 30-year Treasury constant maturity rate from the Federal Reserve Statistical Release. Data is available only from 1977, and both rates fluctuate over time, yet the spread between the two rates has been relatively constant. Taking a conservative approach, I exclude years that show extreme spreads, which were over 3% during the 2008 crisis, and find an average spread of 1.24% over the period 1977 to 2017. One can see the movement of these two rates in Figure 1.2.[28]

I use data from National Income and Product Accounts (NIPA henceforth) and Fixed Assets Tables (FAT henceforth) from 1954 to 2016 to estimate the share of capital α. The estimated value is 0.3043. The estimated value of the annual capital depreciation rate δ using the same dataset is 3.64%, which is higher than the value used in other literature. This is mainly due to the broad definition of nonresidential capital: I include consumer durable goods, whose high depreciation rate causes the average depreciation rate to go up. I discuss more details about my estimation, the definition of variables, and relevant literature (e.g. Cooley and Prescott [1995] and

[27] Note that a model period is 20 years and thus all parameters are adjusted to annual values.

[28] Specifically, I use data from the Federal Reserve Statistical Release - H15 - Selected Interest Rates.

Gomme and Rupert [2007]), in Appendices A.5.1. and A.5.2. I set the property tax rate as $\tau^h = 0.01$ following the literature and leave the remaining tax rates to internal calibration.[29] Mortgage interest is fully deductible ($\tau^m = 1$), and the deduction rate for the value of rental structures $\tau^{ll} = 0.023$ following Sommer et al. (2013), who estimated τ^{ll} by multiplying the annual depreciation rate 3.63% of rental structures by the composition of structures in rental units 64% (Davis and Heathcote 2007). The social security benefit (pension) level tr is estimated by using the U.S. gross pension replacement rate of 0.38 reported in the 2016 OECD Pensions Statistics.[30] Notably, pensions are not funded from a separate tax source, but rather are funded by the general income tax in the model. I assume that social security income of retired agents is taxable. As for the human capital transfer and productivity shock processes, I modify the transition matrices provided by De Nardi and Yang (2016), in which one model period spans 20 years, to fit into my model.

Internal Calibration The remaining nine parameters are calibrated internally. Let $\Theta = \{\beta, \phi_1, \phi_2, x_b, \tau_b, \tau_y, \omega, \eta, H\}$ be the vector of structural parameters to be calibrated. The vector $\hat{\Theta}$ is chosen by minimizing the sum of squared differences between nine simulated model moments ($\bar{F}_n(\Theta)$) and data moments ($\bar{F}_n$):

$$\hat{\Theta} = \min_{\Theta} \sum_{n=1}^{9} \left(\bar{F}_n - \bar{F}_n(\Theta) \right)^2,$$

[29] Saez and Zucman [2016] reports that the Survey of Consumer Finances (SCF) data over 1989-2013 on average shows an effective property tax rate of near 1% in the U.S.

[30] OECD publishes the gross pension replacement rate, which is defined as gross pension entitlement divided by gross pre-retirement earnings. The figure is measured in percentage of pre-retirement earnings by men.

Parameter		Value	Moment	Model	Data
Discount Factor	β	0.933	Capital / Output Ratio	1.666	1.672
Bequest Motive	ϕ_1	-0.055	Bequest / Wealth Ratio	1.25%	1.03%
Bequest Utility Shifter	ϕ_2	1.247	90th perc. of Bequest / Income	5.292	4.340
Exemption Level	x_b	9.627	Frac. of Estates paying taxes	1.0%	2.0%
Estate Tax Rate	τ_b	0.307	Estate tax / Output Ratio	0.33%	0.33%
Income Tax Rate	τ^y	0.299	Gov. spending / Output Ratio	19.2%	19.1%
Consumption Share	η	0.827	Housing / Non-Durable Cons.	0.254	0.256
Fixed Cost (Landlords)	ω	0.005	Landlord / Homeowner Ratio	0.106	0.100
House Supply	H^s	1.224	Homeownership Rate	66.1%	65.0%

Table 1.3: Internally Calibrated Parameters

The nine moments are chosen in consideration of their relevance to the questions addressed by the paper and the tight relationship between certain parameters and certain moments for the given functional forms. The moments are taken from various data and literature sources and their corresponding values are summarized in Table 1.3. Note that the National Income and Product Accounts and Fixed Assets Table from 1954 to 2016 are extensively used for several target moments. For conciseness, I denote these sources as NIPA and FAT henceforth. First, I use the nonresidential fixed assets to output ratio to discipline discount factor β. Nonresidential fixed assets and output are measured using NIPA and FAT data. The bequest to wealth ratio and the 90th percentile of bequests divided by median income are chosen to discipline ϕ_1 and ϕ_2 following De Nardi and Yang [2016]. Gale and Scholz [1994] estimate the bequest to wealth ratio as 1.18%, including intervivos transfers between generations. The 90th percentile of bequests is estimated in Hurd and Smith [2001] using the Asset and Health Dynamics among the Oldest Old (AHEAD) survey and Health and Retirement Study (HRS). Median household income is estimated using the Current Population Survey (CPS) data for year 1994.

The estate tax exemption level x_b is calibrated to match the fraction of bequest-leaving parents who pay taxes, and the estate tax rate τ_b is calibrated to match the ratio of revenue from the estate tax to output (Gale and Slemrod 2001). The income tax rate τ^y is calibrated to match the ratio of government consumption expenditure to output, which is measured from NIPA. The consumption share parameter η is used to match the ratio of personal consumption expenditure on housing services to consumption expenditure on nondurable goods and services, using the NIPA data. Chambers et al. [2009a] compute the ratio of landlords to homeowners from American Housing Survey (AHS) data, using the fraction of homeowners who claim to receive rental income. I use their value to discipline the parameter governing the fixed cost to landlords ω. Lastly, the homeownership rate is targeted as 65%, which is the standard long-term value used in the literature, and this value disciplines the calibration of the fixed housing stock supply H^s.

1.5.2.1 Properties of the Calibrated Baseline Model

Moments The baseline model closely matches the eight model generated moments to the corresponding data moments, as shown in Table 1.3. To further check the properties of the baseline model, I compare several key statistics from the model with non-targeted data moments in Table 1.4. First, I compare the fraction of owner-occupiers with gross mortgage debt, which measures how likely agents are to borrow. From 1994 to 1998, 65 percent of homeowners had gross mortgage debt, according to American Housing Survey (AHS) data. The baseline economy exhibits fewer households in debt compared to the data. Second, the housing stock to output ratio (qH^s/Y) is greater in the model than in the NIPA data, while the equilibrium housing price to rent ratio is within the range reported by Garner and Verbrugge [2009], who use data from the Consumer Expenditure Survey (CE) 1982–2002. Lastly, the ratio of expenditure on housing services to labor income is below the estimated value (0.25) in Davis and Ortalo-Magné [2011]. In a nutshell, while the baseline model economy's households store wealth heavily in housing stock and depend less on mortgage debt than in the data, the model does not deviate excessively from the reasonable range of U.S. data moments.

Note that the interest rate in the calibrated economy is 6.77%, which is close to the level of the 30-year Treasury constant maturity annual rate 6.58% in the beginning of 2000. A high interest rate in a model with a standard CRS technology is not rare: for example, Fernández-Villaverde and Krueger [2011] assume an arbitrary 4% annual interest rate instead of the model implied annual interest rate of 13.75%.[31] In contrast, many papers use a high interest rate rather than choosing a lower interest rate in the calibrated equlibrium: e.g. Gervais [2002] (8.17%), Yang [2009] (8.2%), Chambers et al. [2009a] (5.43%) and Kiyotaki et al. [2011] (6.69%). I follow the literature and choose to calibrate my model to average data moments (e.g. capital to output ratio) from NIPA, which imply a high interest rate.

Wealth Distribution I compare the model-implied wealth distribution to the data. I compute the wealth Gini index (Table 1.5) and total wealth holdings of

[31] In a stationary equilibrium, CRS technology implies the following condition: $\frac{K}{Y} = \frac{\alpha}{r+\delta}$ (Fernández-Villaverde and Krueger 2011).

Moment	Model	Data
Share of Homeowners in Debt	0.29	0.65
House to Output ratio	1.828	1.203
House Price to Rent ratio	14.5	8∼15.5
Imputed Rent to Wage ratio	0.16	0.25
Annual Interest Rate	6.77%	6.58%

Table 1.4: Moments Not Targeted in the Estimation

top percentile households (Table 1.6), employing the Survey of Consumer Finances dataset. I report all ten waves released by the Board of Governors of the Federal Reserve System, which show that wealth inequality has increased since 1989. I compare the reported figures to model analogs in the bottom row where I include only households with positive labor income and positive net worth in the data to be consistent with the model. The model does not match the most recent data on wealth inequality, yet its implications are within the historical range of the data. This suggests that the model is a reasonable laboratory to study the effect of several potential policy suggestions.[32]

Wave	89	92	95	98	01	04	07	10	13	16	Model
Gini	0.68	0.68	0.68	0.69	0.71	0.73	0.73	0.75	0.76	0.77	0.69

Data Source: Survey of Consumer Finances: wave 1989∼2016

Table 1.5: Wealth Gini Index

Further breakdown of the wealth distribution in the benchmark model shows different levels of wealth inequality among landlords, owner-occupiers and renters. As expected, wealth inequality, as measured by the wealth Gini index, is largest

[32]To understand the mismatch, I compare the wealth Gini index with a new model without housing stock, i.e. similar to De Nardi and Yang [2016], and get 0.83. This reveals that the low Gini index for housing stock is driving the Gini index to be lower in the model.

Wave	Percentile					
	60	40	20	10	5	1
Data						
1989	97.28	88.33	69.11	51.27	36.96	15.79
1992	97.19	88.05	68.55	50.97	37.29	16.48
1995	97.26	88.13	68.55	51.13	37.67	18.66
1998	97.58	88.62	69.45	52.18	38.07	17.39
2001	97.71	89.86	72.2	55.13	41.42	20.06
2004	97.97	90.86	74.14	57.82	43.98	21.39
2007	98.02	90.81	74.33	58.07	44.34	20.65
2010	98.66	92.68	77.09	60.56	45.81	22.04
2013	98.71	92.89	77.76	62.03	48.27	24.30
2016	99.03	93.53	78.83	62.83	48.53	24.16
Model						
	98.98	88.93	68.04	51.09	38.36	19.67

Source: Survey of Consumer Finances: wave 1989∼2016

Table 1.6: Total Wealth held by Households in the Top Percentile (%)

among renters, followed by owner-occupiers and landlords. Below, I use these figures as a benchmark to compare the impact of policy changes on the wealth distribution for different groups.

	Landlord	Owner-occupier	Renter
Wealth Gini Index	0.50	0.53	0.64

Note: This table shows the wealth Gini index of the baseline model economy for different groups defined by housing tenure.

Table 1.7: Wealth Gini Index by Housing Tenure Choice

Asset Portfolios I now discuss the baseline model economy's implications for life-cycle patterns of asset accumulation and homeownership. First, Table 1.8 shows that the distribution of end of period financial assets (in levels, left column) is hump-shaped over the agent's lifecycle, i.e. financial assets peak at middle-age and remain positive yet smaller at old age due to bequest motives. Second, young agents use mortgage debt heavily, while middle-age agents carry little mortgage debt, in part due to inheritances. Third, the middle-aged group holds the most housing, while agents hold less housing stock in old age. However, housing wealth exhibits smaller differences across generations than financial assets. Note that young agents hold more in housing than in financial assets, while middle-aged agents hold more financial assets than housing. This is consistent with the notion that young agents take advantage of mortgage loans to purchase housing despite low earnings, and then accumulate more financial assets as they age, with the help of inheritances from their parents.

	Young	Middle	Old
Deposit (A)	1.7	12.9	2.3
House (B)	9.0	11.5	7.5
Mortgage (C)	4.3	0.2	0.0
Wealth(A+B-C)	6.5	24.3	9.8

Table 1.8: End of Period Assets and Mortgage Debt by Age

Housing Distribution I split the support of the housing stock distribution into three categories (small, medium and large), to show how each policy experiment would change the distribution of housing owned.[33] Note that in my model, the level of housing stock owned does not necessarily represent the size of an individual house, but rather represents total housing wealth that households own. For example, owning 5 units of housing in the model could represent a single unit of size 5, or two units of sizes 2 and 3. In short, we should not interpret the distribution of housing

[33]For computing the distribution of house ownership (h'), I set the first housing grid point in the model as small, and housing grid points 2$\sim$7, of which the maximum value is 4 times greater than the value of the first grid point, as medium. I denote the remaining housing grid points as large.

ownership in this paper as the house size distribution. However, by analyzing the distribution of housing ownership, we can see how our policy experiments change the distribution of housing demand across homeowners.

In addition to the distribution of housing stock owned, my model allows me to report the distribution of housing occupied, i.e. the distribution of housing services s. Using data from the American Housing Survey (AHS) (U.S. Census Bureau, 2017), I can compute the shares of housing units occupied by size. I define small homes as housing units of size below 1,000 square feet, medium homes as units between 1,000 and 3,000 square feet, and large-size homes as units above 3,000 square feet. As the housing services grid in my model represents the value of housing rather than house sizes, I match the model simulated shares of households to the share in each housing bin from the AHS data and assign relevant grids.[34] Table 1.9 shows the share of households occupying each size of house. Note that while the distribution of owned housing enables us to see how policy experiments change asset holdings, the distribution of housing occupied shows the changes in consumption of housing.

	Small	Medium	Large
AHS (2017)	23%	67%	10%
Model	37%	53%	10%

Note: Small homes occupied are those smaller than 1,000 ft^2, medium homes are those between 1,000 and 3,000 ft^2, and large homes are those over 3,000 ft^2 in the American Housing Survey (2017).

Table 1.9: Distribution of Occupied Housing (Service)

[34]For computing the distribution of housing services (s), small homes are the first housing grid point, medium homes are the second, third and fourth housing grid points, and large homes are the rest of the housing grid points.

1.6 Experiment 1: Alternative Down Payment Requirements

In this section, I use the calibrated model to study the effect of down payment regulations. Households reallocate their resources in response to the changes in the down payment requirement, represented by parameter θ. I vary the θ value from 0.1 to 0.4, in increments of 0.1, and report changes in asset allocations and the wealth distribution in the model economy. Note that as this paper does not consider the mortgage market explicitly, changes to down payment ratios do not directly affect the mortgage interest rate. Only changes in the overall level of interest rates affect the incentive to take on mortgage loans. Therefore, I assume that the mortgage spread (ι) increases when the down payment ratio is lower than 20%. In practice, lenders require Private Mortage Insurance (PMI) for mortgage loans in excess of 80% of underlying assets (i.e. the home value) to minimize risk. On average, PMI premiums vary from 0.55% to 2.25% of the loan value.[35] I assume that homeowners who borrow more than 80% of home value must pay a 1.4 percentage point increase in the mortgage spread. In a nutshell, this reduced-form adjustment to the model makes a lower down payment ratio less attractive to the borrowers.[36]

θ	Homeowner Share	Landlord Share	House Price(A)	Rent(B)	A/B	Int. Rate
0.40	60.2%	6.91%	2.24	0.153	14.69	6.7657%
0.30	61.2%	7.02%	2.27	0.156	14.57	6.7706%
0.20	66.1%	7.04%	2.31	0.159	14.51	6.7753%
0.10	69.7%	7.27%	2.37	0.164	14.44	6.7854%

Note: Parameter $\theta = 0.2$ represents the baseline model economy.

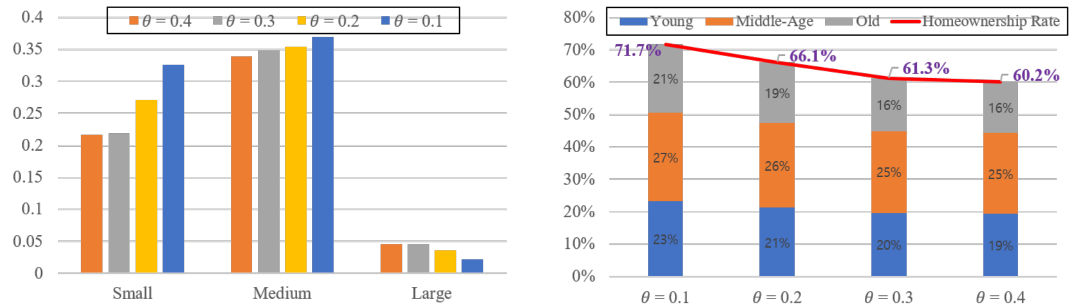
Table 1.10: Effects of the Down Payment Requirement

1.6.1 Aggregate Effects

When the down payment requirement changes, marginal renters and small-size homeowners are directly affected, since the mortgage debt constraint first binds for those households that do not hold sufficient equity or households just above the required equity level to purchase housing. Households that are financially constrained by the regulation cannot make their preferred optimal asset choices. Tables 1.10 and 1.11 report equilibrium statistics for each policy change. When the down payment requirement becomes tighter, i.e. when θ is greater than the baseline value $\theta = 0.2$ and more equity is required to purchase housing, one can witness the following: first, as the limit of mortgage loans is shrinking, agents save more in deposits as renters rather than purchasing housing stock (the deposit-to-housing stock ratio increases from 59.8 % to 62.1%). Second, price variables move in the expected direction. When the down payment regulation becomes tighter, fewer agents can own housing, and the equilibrium housing price falls as a result of diminishing housing demand.

[35] Table 2 from Goodman [2017] reports the mortgage premiums of PMI, depending on FICO scores. In this experiment, I choose the average number of 1.4%.

[36] The objective of this additional assumption is to examine how the economy responds differently to the decline in the required θ from 0.2 to 0.1, if we consider mortgage interest rate adjustments in the financial market.



(a) Changes to House Size Distribution

(b) Changes to Homeownership by Age

Note: Vertical axis of panel (a) is respective share of population. Figures in panel (b) represent shares of sub-groups in total population.

Figure 1.3: Changes to Homeownership

Rent also falls due to overall decrease in demand for housing services. The interest rate falls as agents pull their resources out of housing stock and instead save in deposits. Third, the homeownership rate falls (66.1% to 60.2%), especially among old households (19% to 16%, as shown in the right panel of Figure 1.3). Lastly, increased housing demand by the wealthy households taking advantage of lower housing prices increases the number of households purchasing large size houses. Also, as households with less equity become renters, demand for small and medium size houses fall (left panel, Figure 1.3). A policy change to the opposite side, i.e. θ falling from 0.2 to 0.1, has opposite effects, as I will discuss in detail in the next Section.

θ	Deposit (A)	Housing (B)	A/B
0.4	0.0171	0.0275	62.1%
0.3	0.0170	0.0278	61.1%
0.2	0.0169	0.0283	59.8%
0.1	0.0167	0.0290	57.6%

Table 1.11: Effects of the Down Payment Requirement on Assets

1.6.2 Intermediate Stages

To better understand the effects of changes in the down payment requirement, I set up intermediate stages between the two steady-state equilibria (one with $\theta = 0.2$ and the other with $\theta = 0.1$) for expository purposes.[37] More specifically, I set $\theta = 0.1$ as a new down payment requirement and explore two intermediate stages between the two steady state equilibria: intermediate stage 1 (denoted as *Price Fixed*), in which the down payment requirement has changed to its new level but all prices are held constant; and intermediate stage 2 (denoted as *Price Chg.*), in which only house prices change to their new equilibrium level.[38] Note that each intermediate stage is not in equilibrium. Yet, this is a useful method to understand the underlying incentives and choices of households in response to policy changes. As an overview, Table 1.12 summarizes the changes of prices, tenure choices, house distribution, and asset composition for each intermediate stage up to the next steady-state equilibrium under $\theta = 0.1$.

1.6.2.1 Intermediate Stage 1: $\theta = 0.1$ with Price fixed

When the down payment requirement is relaxed with no price changes (*price fixed*), there is a noticeable increase in the number of small-size homeowners as well as the total number of homeowners. Marginal renters now take advantage of mortgage lending and become homeowners. As a result, the housing market is now

[37] Note that the movement in the interest rate in this scenario is so small that it has no noticeable effect on the asset allocation and wealth distribution, and thus I omit that intermediate stage.

[38] After this stage, U.S. economy moves to a new steady state, where all prices change to their new equilibrium levels under the down payment ratio of $\theta = 0.1$.

		Baseline	Price Fixed	Price Chg.	New Eqm.
Price	House Price (q)	2.312	2.312	2.372	2.372
	Rent (ρ)	0.159	0.159	0.159	0.164
	q/ρ	14.5	14.5	14.9	14.4
	Interest Rate (%)	6.78	6.78	6.78	6.79
Tenure	Homeownership(%)	66.1	67.9	52.8	69.7
	Landlord (%)	7.0	4.0	1.3	7.3
House	Small	0.272	0.299	0.211	0.294
	Medium	0.354	0.344	0.303	0.381
	Large	0.036	0.036	0.015	0.023
Mortgage	Household in Debt	0.193	0.201	0.087	0.215
	(% of Homeowners)	29.2%	29.6%	16.5%	30.9%

Note: Original housing prices and rents are one hundredth of reported numbers.
Figures in "House" row represent shares of population.

Table 1.12: Quantity and Price Effects of Relaxed Down Payment Requirements

	Baseline ($\theta = 0.2$)			Price Fixed ($\theta = 0.1$)		
	Small	Medium	Large	Small	Medium	Large
Owner-occupier (A)	0.272	0.303	0.016	0.299	0.306	0.016
Landlord (B)	-	0.051	0.020	-	0.038	0.020
Homeowner (A+B)	0.272	0.354	0.036	0.299	0.344	0.036

Note: Figures in the table represent shares of population.

Table 1.13: Changes in Housing Distribution: Price Fixed

in excess demand, which tends to push house prices up.

1.6.2.2 Intermediate Stage 2: $\theta = 0.1$ with Housing Price Change

The increase in the housing price (2.6%), while rent stays at the same level, deters transitions from renters to homeowners, since households need more equity even with the relaxed down payment. Table 1.14 shows that demand for each house size decreases, especially for small size houses. The price effect is effectively driving marginal homeowners to become renters and thus the number of renters at this stage is greater than the number in the baseline economy. Also, an increased housing price to rent ratio (from 14.5 to 14.9) reduces the incentives to become a landlord.

	Price Fixed ($\theta = 0.1$)			Housing Price Chg ($\theta = 0.1$)		
	Small	Medium	Large	Small	Medium	Large
Owner-occupier (A)	0.299	0.306	0.016	0.211	0.292	0.012
Landlord (B)	-	0.038	0.020	-	0.011	0.003
Homeowner (A+B)	0.299	0.344	0.036	0.211	0.303	0.015

Note: Figures in the table represent shares of population.

Table 1.14: Changes in Housing Distribution: Housing Price Change

1.6.2.3 New Steady State: $\theta = 0.1$

The increased rental demand attributable to the rise in the housing price causes rent to increase. This price change has an additional feedback effect: as the relative price of housing gets cheaper (specifically, as the ratio of housing price to rent falls from 14.9 to 14.4 in Table 1.15), agents utilize more mortgage loans and purchase more housing stock (the fraction of indebted housedolds increases from

	Housing Price Chg ($\theta = 0.1$)			New Steady State ($\theta = 0.1$)		
	Small	Medium	Large	Small	Medium	Large
Owner-occupier (A)	0.211	0.292	0.012	0.294	0.315	0.016
Landlord (B)	-	0.011	0.003	-	0.066	0.007
Homeowner (A+B)	0.211	0.303	0.015	0.294	0.381	0.023

Note: Figures in the table represent shares of population.

Table 1.15: Changes in House Distribution: a New Steady State

8.7% to 21.5% in Table 1.12). At the new equilibrium, more agents live in their own housing, at the cost of an increased housing price. To comprehend the increase in rent, we need to consider the distribution of housing service consumption s. Table 1.16 shows that the relaxed down payment requirement induces agents to live in larger houses, mostly because of owner-occupiers. Lastly, as resources move from saving in deposits to purchasing housing stock, the interest rate increases slightly.

		Small	Medium	Large
$\theta = 0.2$	Total	0.369	0.532	0.10
	Owner-occupier	-	0.494	0.096
$\theta = 0.1$	Total	0.349	0.552	0.10
	Owner-occupier	-	0.527	0.097

Note: Small homes are housing occupied under 1,000 ft^2, medium homes over 1,000 and under 3,000 ft^2, and large homes are over 3,000 ft^2 in the American Housing Survey (2017).

Table 1.16: Housing Distribution Occupied (Service)

1.6.3 Distributional Effects

Table 1.17 shows that a relaxed down payment requirement alleviates wealth inequality, while a tightened down payment requirement increases wealth inequality. To get a sense of the magnitude of these differences, I compare them to differences over time observed in the U.S. data. From the Survey of Consumer Finances (SCF) data in Table 1.5, the wealth Gini index has increased from 0.68 to 0.77 over the past 27 years. This implies that the Wealth Gini index in the U.S. has increased by 0.003 per year on average during this period. Therefore, by that standard, a down payment requirement change from $\theta = 0.2$ to 0.1 would reverse roughly 2 percent of the recent secular increase in the Gini index (Gini index falls by 0.0016).

θ	Percentile						Wealth Gini	Fin.Gini
	60	40	20	10	5	1		
0.40	99.7	90.1	68.3	51.5	38.1	19.7	0.6972	0.8805
0.30	99.4	90.1	68.6	51.5	38.4	19.8	0.6964	0.8799
0.20	99.0	88.9	68.0	51.1	38.4	19.7	0.6867	0.8732
0.10	99.0	88.8	67.9	50.7	38.2	19.6	0.6851	0.8725

Note: Each figure represents a share of total wealth held by each percentile from the top. $\theta = 0.20$ represents the baseline model economy.

Table 1.17: Distributional Effect of the Down Payment Regulation

A further breakdown of the wealth distribution by housing tenure in Table 1.18 reveals that lower downpayments cause higher wealth inequality among landlords and owner occupiers, but lower inquality among renters.

θ	Landlord	Owner-occupier	Renter
0.4	0.337	0.517	0.649
0.3	0.403	0.522	0.648
0.2	0.496	0.532	0.644
0.1	0.577	0.546	0.644

Note: Parameter $\theta = 0.2$ represents the baseline model economy.

Table 1.18: Wealth Gini Index (by Housing Tenure)

In a nutshell, the downpayment requirements affect wealth inequality, but the magnitude of the changes is very small. Note that households can increase mortgage loans at low cost, as they do not worry about default risks in the model. In this sense, incorporation of default in the model might generate more realistic outcomes, which I leave for future research.

1.7 Experiment 2: Dual Down payment Ratios

In this section, I explore a novel policy of imposing different down payment ratios, $\theta = 0.2$ for landlords and $\theta = 0.1$ for owner-occupiers, so that owner-occupiers can borrow up to 10% more of housing value than landlords. The objective of this experiment is to see what happens to the housing market, tenure choice and wealth distribution if policy discriminates against landlords relative to owner-occupiers. Landlords play a unique role in supplying rental units, and thus one can expect that an unfavorable down payment ratio could disrupt the rental market.

1.7.1 Aggregate Effects

Comparing the fourth ($\theta = 0.2$ & 0.1) and fifth columns ($\theta = 0.1$) in Table 1.19, the differences from adopting two down payment ratios (”dual ratio policy” hereafter) versus a commonly reduced down payment ratio (”common ratio policy”) are the following: first, the homeownership rate under the dual ratio policy increases relative to the benchmark with $\theta = 0.2$, but not as much as under the common ratio policy (from 66.1 % to 69.1%, compared with 69.7% in the common ratio policy), because landlords cannot borrow as much as owner-occupiers. Second, the dual ratio policy has little effect on price variables relative to the benchmark ($\theta = 0.2$).

		$\theta = 0.2$	$\theta = 0.2$ & 0.1^*	$\theta = 0.1$ (Common)
Price	House Price (q)	2.312	2.325	2.372
	Rent (ρ)	0.159	0.160	0.164
	Price-Rent-Ratio	14.5	14.5	14.4
	Interest Rate (%)	6.775	6.779	6.786
Tenure	Homeownership(%)	66.1	69.1	69.7
	Landlord (%)	7.0	6.6	7.3
House	Small	0.272	0.301	0.294
	Medium	0.354	0.357	0.381
	Large	0.036	0.033	0.023
Portfolio	Deposits (A)	0.0170	0.0169	0.0167
	Mortgage Debts	0.0042	0.0046	0.0047
	Housing Wealth (B)	0.0283	0.0285	0.0290
	(%, A/B)	60.0%	59.5%	57.6%
Mortgage	Household in Debt	0.193	0.210	0.215
	(% of Homeowners)	29.6%	30.3%	30.9%

$*$ Down payment ratio θ is 0.2 to landlords and 0.1 to owner-occupiers.

Table 1.19: Aggregate Effects of Relaxed Down Payment Requirements (Two θ)

The increase in the housing price under the dual ratio policy is smaller than the increase under common ratio policy (0.6% vs. 2.6%). Notably, the rent increase is near zero, contrary to our expectation, because the fall in rental supply is muted by a fall in rental demand. Third, the increases in mortgage debt outstanding and the number of households in debt are smaller than the increase under the common ratio policy, reflecting a smaller increase in the homeowership rate and restricted borrowing for landlords.

1.7.2 Distributional Effects

Table 1.20 shows that relaxing the down payment ratio only for owner-occupiers has different effects on the wealth distribution relative to relaxing the ratio for all

	Wealth (Total)	Deposit	Landlord	Owner-occupier	Renter
$\theta = 0.2$	0.687	0.873	0.496	0.532	0.644
$\theta = 0.2\,\&\,0.1$	0.686	0.873	0.478	0.545	0.644
$\theta = 0.1$	0.685	0.872	0.577	0.546	0.644

Table 1.20: Wealth Gini Index for Various Down Payment Regulation

homeowners: first, the decline in wealth inequality is similar (from 0.687 to 0.686 vs. 0.685). Second, wealth inequality among landlords falls slightly rather than increasing (from 0.496 to 0.478 vs. 0.577). The preferential down payment ratio applied to owner-occupiers prevents some homeowners from becoming landlords. In a nutshell, application of dual down payment ratios is less effective than a uniform decline in the down payment ratio, if the policy objective is to affect the housing market. However, if the aim is to boost homeownership with less distortion in the rental market, dual down payment ratios could be a good solution.

1.8 Experiment 3: Repealing the Mortgage Interest Deduction

Homeowners enjoy preferential treatment in the U.S. tax system, to promote the affordability of owner-occupied housing. The mortgage interest deduction has been criticized as favoring homeowners versus renters who are relatively poor. In the literature, potential problems arising from housing tax preferences have been discussed starting in the 1970s (Aron 1970, Rosen 1979, for instance), and Glaeser [2010] associates housing preferences in the U.S. with the housing bubble before the global financial crisis in 2008. The Organization for Economic Cooperation and Development (OECD) recommends avoiding tax policies that favor homeonwership as they can lead to excessive investment in housing (OECD 2011). However, opposition to revising the tax code is also strong. Defenders of tax preferences claim that the administrative costs associated with estimating imputed rent would be immense and that removing tax credits for homeowners would seriously reduce the wealth of homeowners and consequently the whole U.S. economy. In this section, I use my model to study the effect of removing the mortgage interest deduction on the housing market and wealth distribution. The baseline model economy is the same calibrated model as in Section 1.6.

1.8.1 Aggregate Effects

When mortgage interest is no longer deductible from taxable income, becoming a homeowner requires more equity. Housing demand drops as expected, which causes the housing price to fall, and households transition to becoming renters, which causes rents to rise. From Table 1.21, we can find the following: first, reduced incentives to borrow make homeowners depend less on mortgage debt (the share of households in debt falls from 29.6% to 29.2%), and leads to a fall in mortgage debt (from 0.0042 to 0.0040). Second, the homeownership rate falls from 66.14% to 65.18%, and households move their resources from housing wealth to deposits (the deposit to housing wealth ratio increases from 60.2% to 62.6%).

		$\theta = 0.2$	$\theta = 0.2$, no MID*
Price	House Price (q)	2.312	2.236
	Rent (ρ)	0.159	0.160
	q/ρ	14.51	13.97
	Interest Rate (%)	6.78	6.71
Tenure	Homeownership(%)	66.14	65.18
	Landlord (%)	7.04	5.50
House	Small	0.272	0.268
	Medium	0.354	0.352
	Large	0.036	0.033
Portfolio	Deposits (A)	0.0170	0.0171
	Mortgage Debts	0.0042	0.0040
	Housing Wealth (B)	0.0282	0.0274
	(%, A/B)	60.2	62.6
Mortgage	Household in Debt	0.19	0.18
	(% of Homeowners)	29.6	28.2

∗ θ: Down Payment ratio, MID: Mortgage Interest Deduction

Table 1.21: Aggregate Effect of Repealing Mortgage Interest Deduction

1.8.2 Distributional Effects

If the rationale of repealing the mortgage interest deduction is to improve the wealth distribution, the model result is to the contrary. As homeownership becomes more costly with an increased housing price and no mortgage interest deduction, more equity is required than before, and thus only wealthier households can now become homeowners. On the other hand, from Table 1.22, we can see that wealth inequality has decreased for deposits. Note also that the Gini indices for different housing tenure groups suggest that inequality increases among homeowners (both landlord and owner-occupier groups).

	Wealth (Total)	Deposit	Landlord	Owner-occupier	Renter
$\theta = 0.2$	0.6867	0.873	0.496	0.532	0.644
$\theta = 0.2$ with no MID	0.6871	0.872	0.510	0.536	0.644

Note: MID stands for mortgage interest deduction

Table 1.22: Distributional Effects (Repealing MID)

1.9 Conclusion

In this paper, I explore the impact of changes to the down payment ratio or the mortgage interest deduction on the housing market and the wealth distribution in the U.S., using a three-period lifecycle model. While the effect of down payment regulations is strong for the housing market and mild for the wealth distribution, the overall direction of changes are in line with our expectations. I further show that a dual down payment ratio that favors owner-occupiers could cause less effects on the rental markets at the cost of a smaller impact on the distributions of housing tenure and the wealth distribution. On the other hand, repealing the mortgage interest deduction reduces the incentives to become homeowners as the policy revision requires more equity for homeowners. This limited access to homeownership leads to an increase in wealth inequality. The analysis in this paper highlights potential risks from housing policy changes, especially in terms of the wealth distribution. As wealth inequality is becoming a major policy concern for the U.S. economy, as well as most other advanced countries, a more careful analysis of policy impacts should be advanced before actual enactment of housing policy revision.

Chapter 2: Heavy property tax on multiple home owners: How much does it decrease wealth inequality?

2.1 Introduction

Housing shortages and rising housing prices in major metropolitan areas are major concerns in Korea. The Korean government has intervened heavily in housing markets, using various tax and financial policies to discourage speculative housing transactions and to stabilize the housing market. For example, the debt-to-income ratio (DTI) and loan-to-value (LTV) ratio are frequently changed as prudential policy instruments to curb excessive housing investments by the wealthy and multiple home owners. Notably, Korea has a unique real estate tax scheme to discriminate among homeowners based on the number of housing units owned and the market price of housing.[1] The Korean government made an announcement on Dec.16, 2019 to increase the comprehensive real estate tax rate for single house owners by 0.1∼0.3% while further increasing the tax rate for owners of three or more houses by 0.2∼0.8%.[2,3]

[1] Multiple home owners also suffer from unfavorable treatment in financing (lower LTV ratios are applied) and other taxation (higher capital gains tax rates are applied).

[2] The comprehensive real estate tax is a local property tax on housing and land. I explain more details in Section 2.2.

[3] In recent years, the Moon administration has set out a series of housing policies (18 times since May 2017) with an objective to suppress demand from homeowners who own multiple homes by

	Low-income	Middle-income	Upper-income
2006	49.7	55.3	67.0
2018	47.2	60.1	75.2

Source: Korea Housing Survey (Annual), Ministry of Land, Infrastructure and Transport

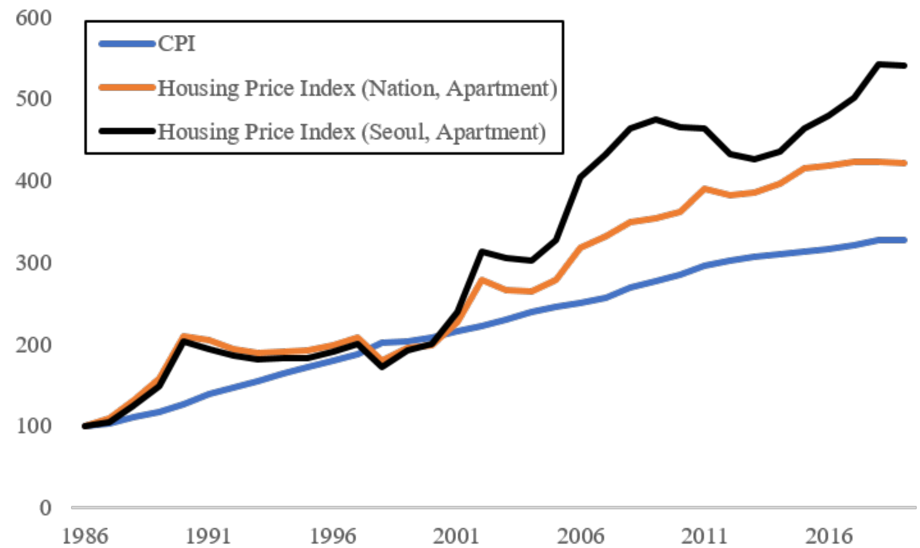
Table 2.1: Homeownership Rate by Income Level (%)

One rationale behind this heavy taxation on multiple home owners is that it could decrease wealth inequality. Political discussion regarding the tax revision has focused mostly on how much progressivity should be built into the tax system, rather than on whether the tax system is actually a solution to the wealth inequality issue. This is because housing in Korea is a lucrative asset, and is viewed as being held mostly by wealthy, high-income earners (Table 2.1).[4] Research on this topic is rare, as no other OECD countries have a property tax scheme similar to Korea.

The question I ask in this paper is how much the Korean property tax scheme, which imposes a heavy tax rate on housing owned by multiple home owners, decreases wealth inequality. As the complexity of the Korean tax system prevents me from analyzing it in full detail, I build a stylized dynamic lifecycle model, which is initially calibrated to the Korean economy with a uniform property tax rate ($\tau^h = 0.13\%$). Then I undertake counterfactual experiments with dual property tax rates: a lower tax rate imposed on households who own a small number of housing units and a higher tax rate imposed on households who own a large number of

imposing punitive taxation on multiple home owners in major regions across the nation. (Financial Times "Korea imposes tougher taxes on properties to curb price surge" (Sep. 13, 2018))

[4] As Ronald and Jin [2010] point out, Korean housing prices (particularly, apartment prices) have increased faster than incomes and consumer prices (Figure 2.1 extends a graph reported in their paper).



Source: Korea Appraisal Board, National Statistics Office

Figure 2.1: Housing Price Index and Consumer Price Index (1986 = 100)

housing units. By comparing steady states, I numerically show the effects of the discriminative property tax scheme on the housing market and wealth inequality.[5]

Households in my model work for four periods earning stochastic income, and then retire and receive a pension for the remaining four periods. The model features voluntary bequests as in De Nardi [2004] and housing tenure choices as in Sommer et al. [2013] and Sommer and Sullivan [2018]. As the housing tenure choice in my model allows me to separate owner-occupiers and landlords, changes in the rental market can be explained through transitions in housing tenure.[6] Note that households supply the majority of rental units in Korea, supplying 78.9% of total

[5]Since the smallest housing grid point in my numerical solution cannot represent a single house, I alternatively choose to experiment with a property tax scheme that separates small home owners and large home owners. In addition, I refer to the Korean tax scheme as "discriminative" in that the tax system treats the same households differently according to the number of homes they own, regardless of the homes' aggregate market value.

[6]One feature of my model is that homeowners provide rental supply rather than financial institution as in Gervais [2002].

rental housing (Shin and Yi 2019).[7]

When the model economy introduces a higher property tax rate for owning a large stock of housing, the asymmetry in tax rates induces households to purchase less housing, leading to a decreased number of landlords and a fall in rental supply. Both housing prices and rents increase due to excess demand, but the overall homeowership rate increases. Note that the first set of counterfactual tax schemes are constructed to hold property tax revenue constant, i.e. the initial uniform tax rate falls to a lower level to incorporate a second higher tax rate.[8] Reallocation of wealth from owners who hold a large housing stock to the rest of the households makes wealth inequality fall. However, the distributional effects are very small relative to the change in the tax rates. For example, for the second set of alternative tax rates (0.025%, 0.28%) ("Exp 1-2"), even though the higher tax rate is more than double the initial tax rate, and ten times greater than the tax rate for small housing stocks, the wealth Gini only falls from 0.6259 ("Benchmark") to 0.6256.

I construct a second set of experiments to study the recent policy change in Korea that increases property tax rates disproportionately, i.e. increasing the tax rate for multiple home owners more than the tax rate for single home owners. I experiment with three sets of tax rates: {(Exp 2-1), (Exp 2-2), (Exp 2-3)} =

[7] A special type of rental unit in Korea, so-called "Chonsei", is not considered in this paper. "Chonsei" renters pay an upfront deposit to the landlords instead of periodic rents and receive it back when the term is over. For the purpose of this paper, "Chonsei" is only different in terms of the timing of payment from standard housing rentals and both rents should be equal in equilibrium. Moreover, the share of "Chonsei" units in total rental units has fallen from 50% in 2006 to 36% in 2018, and the inclusion of another tenure choice would complicate the analysis.

[8] The baseline uniform property tax rate is 0.13%. Two sets of property tax rates are considered in the first set of counterfactual experiments: {(Exp 1-1), (Exp 1-2)} = {(0.1%, 0.17%), (0.025%, 0.28%)}.

{(0.26%), (0.13%, 0.26%), (0.13%, 0.39%)}. As these revisions weakly increase tax burdens of all homeowners, economies with the first tax scheme exhibits an increased wealth Gini.[9] However, when the last tax scheme is introduced, the wealth Gini falls compared with the benchmark economy. This result supports the view that punitive (property) taxation on multiple home owners can redistribute from wealthy homeowners with multiple units to less wealthy small homeowners or renters (Table 2.15). Note that the distributional effect is also small in this experiment: the wealth Gini falls from 0.6259 (”Benchmark”) to 0.6258 (”Exp 2-3”)

In a nutshell, this paper shows that imposing a heavy property tax on multiple home owners does decrease wealth inequality. However, the distributional gains come at the cost of wealthy households' welfare losses: e.g. while average consumption increases, consumption of households in the top 25% wealth percentile falls in all experiments. Also, as my model does not incorporate heterogeneous asset returns or productivities of households, if multiple home owners earn more than other households investing in assets or businesses, the social opportunity costs of redistribution could be high.[10] Lastly, this paper studies the wealth distribution rather than the aggregate wealth level. If the adverse effects of the policy on the total wealth or productivity of the economy were considered, the evaluation of the property tax scheme would be different. Therefore, I argue that one should be cautious in using my results to defend the current Korean tax scheme.

[9] The effects on asset allocations and housing tenure are similar to the first experiment. Note that the property tax scheme in this paper is proportional, which makes it regressive.

[10] From a purely theoretical view, heavy taxation on multiple home owners reduces their wealth accumulation from asset returns of business income, and thus could decrease wealth inequality further. This, of course, would also cost more to large home owners than my analysis would indicate.

The rest of the paper proceeds as follows. Section 2.2 overviews the housing property tax scheme of Korea. Section 2.3 explains the model features used in this paper. Section 2.4 outlines the overlapping generations model. Section 2.5 defines the steady-state equilibrium. Section 2.6 discusses the calibration of the model. Section 2.7 discusses properties of the benchmark economy. Section 2.8 conducts experiments using the model and Section 2.9 concludes.

2.2 Overview of Housing Property Tax Scheme of Korea

Value of Housing		General	Multiple Home Owner
(S) $\leq$ 1.76	(M) $\leq$ 1.33	0.6%	0.8%
(S) 1.76 $\sim$ 2.24	(M) 1.33 $\sim$ 1.81	0.8%	1.2%
(S) 2.24 $\sim$ 3.19	(M) 1.81 $\sim$ 2.76	1.2%	1.6%
(S) 3.19 $\sim$ 9.22	(M) 2.76 $\sim$ 8.79	1.6%	2.0%
(S) 9.22 $\sim$ 16.21	(M) 8.79 $\sim$ 15.78	2.2%	3.0%
(S) 16.21 $<$	(M) 15.78 $<$	3.0%	4.0%

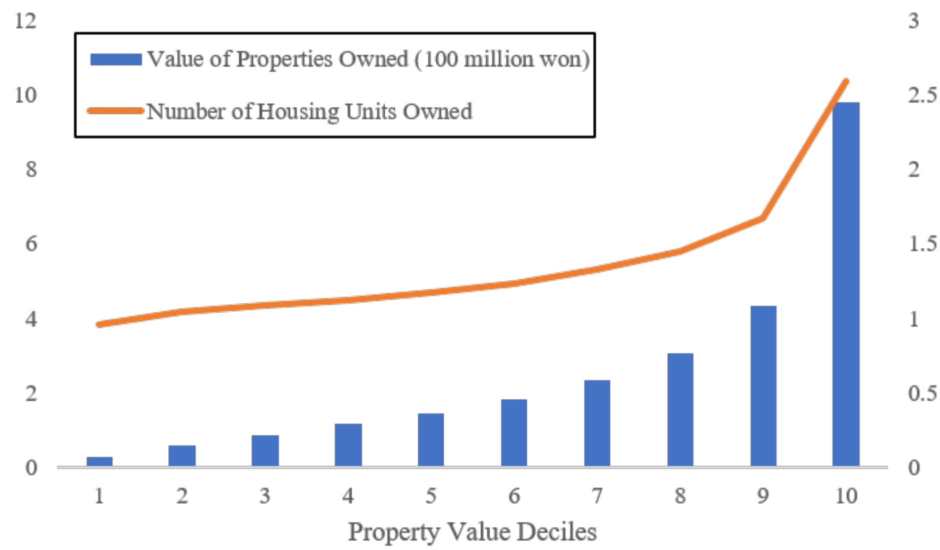
Source: Ministry of Economy and Finance.
(S) Single home owner (M) Multiple home owner, all figures are in billion won
Multiple Home Owner: Owning more than three housing units, or two housing units in speculative regions

Table 2.2: Comprehensive Real Estate Tax

Homeowners in Korea pay a property tax, levied by the national government, and a comprehensive real estate tax, levied by regional governments. The comprehensive real estate tax was introduced in 2005 to increase the equity of the tax burden on the possession of real estate, and to stabilize the price of real estate.[11] The comprehensive real estate tax is only imposed on housing properties valued above 600 million Korean won (500 thousand US dollars). Table 2.2 summarizes the

[11] This rationale comes from article 1 of the Comprehensive Real Estate Tax Act.

tax rates, which vary with the value of housing and the number of housing units owned. Single home owners can enjoy an additional deduction, which is another type of tax discrimination against the number of housing units owned.



Source: Source: 2018 Statistics of House Ownership

Figure 2.2: Number of Housing Units Owned by Property Value Decile

The tax base of the housing property tax does not have a deduction based on property value like the comprehensive real estate tax, but its tax rate differs from 0.1% to 0.4% depending on the value of the property. In summary, homeowners in Korea pay the sum of the (standard) housing property tax and the comprehensive real estate tax, and as multiple homeowners hold more expensive housing (Figure 2.2), they face higher tax rates on average.

2.3 Model

I use an eight period lifecycle model in which households face uninsurable earnings risk and make ”warm glow” bequests and housing tenure choices. Households work for the first four periods earning labor income, and then receive pensions for the next four periods.[12] The bequest utility function follows De Nardi [2004], and total bequests are assumed to be fully taxed and redistributed to the working households.[13]

2.3.1 Households

Income Households earn stochastic incomes which are uninsurable following Aiyagari [1994]. The labor productivity $e^{z_t^i+\varepsilon_t}$ consists of deterministic age-efficiency profiles ε_t and productivity shocks z_t^i.[14] The productivity shocks follow an AR(1) process as $z_t^i = \rho_z z_{t-1}^i + \mu_t^i$, where $\mu_t^i \sim N(0, \sigma_z^2)$.

Preferences Households consume nondurable good c and housing services s. I assume that the consumption weight on each good is fixed as η and that risk-aversion parameters (γ_1 and γ_2) are not identical following Chambers et al. [2009b] and Cho [2012]. Households enjoy higher utility from owned housing than from rental housing, which is reflected in the model with parameter ψ.[15]

$$u(c, s) = \eta \cdot \frac{c^{\gamma_1}}{1-\gamma_1} + (1-\eta) \cdot \frac{((1-\psi \cdot I^{h'=0}) \cdot s)^{\gamma_2}}{1-\gamma_2} \tag{2.1}$$

[12] We can think of a model period as lasting 10 years, so that households enter the economy at age 20 (model period $t = 1$), retire at age 60 ($t = 5$) and die at the end of age 89 (model period $t = 8$). I assume no death risk in the model, so that households die at the end of period $t = 8$ with probability one.

[13] In other words, I do not assume direct intergenerational links between parents and children.

[14] Note that t represents model periods and i represents households throughout the paper.

[15] ψ takes a value between zero and one. The housing literature often uses this preference specification, e.g. Kiyotaki et al. [2011]. In contrast, alternative models with preferential tax deductions for homeowners could generate enough homeowners in the model even without this assumption (Sommer et al. 2013, Chambers et al. 2009a).

Housing Tenure Housing tenure options in my model follow Sommer et al. [2013]: households can stay in rental housing (”Renter”), live in their own housing (”Owner-occupier”) or rent part of their housing (”Landlord”). Renters consume housing services s at rent p^s. Owner-occupiers hold housing stock ($h' > 0$) at housing price p^h and live in the same units ($h' = s$). There is a linear technology that transforms housing stock h' to housing services s one to one. Landlords hold housing stock ($h' > s$) and supply excess rental units ($h' - s$) to the renters. Only homeowners can borrow ($m' > 0$) against their housing, and pay mortgage interest next period.

All homeowners pay maintenance costs of $\delta_h p^h h'$ and proportional transaction costs are incurred at rate κ^s when households sell their housing stock and at rate κ^p when households purchase housing stock. I assume selling costs are greater than purchasing costs ($\kappa^s > \kappa^p$). Landlords pay an additional fixed cost ω which represents the managerial cost associated with rental units in practice.

Assets and Mortgage Debt Households can either save in deposits (d') and earn interest income at a risk free rate r, or purchase housing stock (h') with mortgage borrowing at a constant rate r^m. Note that mortage debt (m') is limited by down-payment requirement ratio θ as $m' \leq (1-\theta)p^h h'$. Both housing stock and housing services are available in discrete sizes: $h' \in \{0, h(1), ..., h(Q)\} \equiv \mathbb{S}_H$ and $s \in \{\underline{s}, s(1), ..., s(Q)\}$, where Q represents an index for maximum housing size, $\mathbb{S}_H$ is a set of possible house sizes and $\underline{s}$ is the smallest level of housing services available. Note that renters can live in smaller housing units, i.e. $\underline{s} < h(1)$, following Sommer et al. [2013].

Bequest At the end of the last period ($t = 8$), households leave bequests q and benefit according to a warm-glow bequest utility function as in De Nardi [2004]:

$$\phi(d',\, h') = \phi_1[1 + \frac{q}{\phi_2}]^{1-\gamma}, \tag{2.2}$$

where $q \equiv d' + (1 - \kappa^s)qh'$.

I make two assumptions about bequests: first, bequests are equal to a household's end-of-life net wealth after paying selling costs. Second, all bequests are fully taxed and equally redistributed to working households as in Cho [2010].[16]

2.3.2 Firm

A representative firm produces a nondurable good using labor L and capital K with a standard Cobb-Douglas production function: $F(K, L) = K^{\alpha}L^{1-\alpha}$. Factor markets are competitive and capital depreciates at the rate δ. Produced goods can be transformed to capital one to one.

2.3.3 Government

The government levies an income tax at rate τ^y on incomes of households, a property tax with rate τ^h on the housing stock of homeowners and a bequest tax on bequests of the deceased. Tax revenues are used to distribute a lump-sum pension b and a transfer T to working households. Remaining revenues are spent

[16] This simple bequest function creates enough wealth held by old households to create a plausible wealth distribution without having complex intergenerational links between parents and children (refer to De Nardi and Yang 2016).

for government expenditure G. Note that homeowners in Korea do not benefit from income tax deductions for mortgage interest or property tax payments. However, landlords can deduct rental income from taxable income at the deduction rate τ^{ll}.[17]

2.3.4 Financial Intermediary

A financial intermediary channels all financial flows in the market, which include deposits d', capital K and mortgage debt m'. The financial intermediary is involved in all financial asset transactions: it receives deposits from households and supplies mortgage loans to homeowners and capital to firms. The financial institution is risk-neutral and earns no profit from intermediation. I assume that the mortgage interest rate r^m is a fixed spread ι over the risk-free interest rate r and that intermediation of mortgage loans incurs a transaction cost to the financial intermediary at the rate (or price) ι. In this way, the equilibrium conditions for loans and deposits are reduced to the equilibrium condition of the intermediary's balance sheet.[18]

[17]Article 75 of the Restriction of Special Taxation Act stipulates a rental income deduction rate from 20% to 75% depending on the number and size of rental housing units owned.

[18]Formally, the deposit market, mortgage market, and capital market should all independently clear in equilibrium as follows:

$$D = \int_S d'(x)\,\mathrm{d}\lambda,\ M = \int_S m'(x)\,\mathrm{d}\lambda,\ \text{and}\ K^s = K,$$

where D is demand for deposits by the financial firms, M is provision of mortgage loan by the financial firms, and K^s is capital supply by the financial firms. As the financial intermediary is the sole channel of the three financial instruments, the balance of the intermediary's financial statement can be described as an asset market equilibrium condition as in Chambers et al. [2009a].

Asset	Liability
Mortgage Loans (M)	Deposits (D)
Loans to Firms (K)	

Table 2.3: Balance Sheet of the Financial Intermediary

2.4 Dynamic Programming Problem

This section describes the recursive problem households face, using the properties discussed in Section 2.3. Two value functions are used to represent working households (V_w during periods $t = 1 \sim 4$) and retired households (V_r during periods $t = 5 \sim 8$). An indicator function I is extensively used in the model, which equals one when the condition in the superscript is satisfied and zero otherwise.

$$V_w(t, d, m, h, z) = \max_{c,s,d',m',h'} u(c, s) + (1 - I^{w4}) \cdot \beta E[V_w(t+1, d' + T, m', h', z')] + I^{w4} \cdot \beta E[V_r(t+1, d' + T, m', h')] \quad (2.3)$$

subject to:

$$c + p^s(s - h') + I^{h' \neq h} \cdot (\kappa^s \cdot p^h h + \kappa^p \cdot p^h h') + \delta_h \cdot p^h h' + I^{h' > s} \cdot \omega \quad (2.4)$$

$$\leq y - [d' - (1+r) \cdot d] + m' - (1 + r^m) \cdot m + p^h(h - h') - \left[\tau^y \tilde{y} + \tau^h p^h h'\right] \quad (2.5)$$

$$\tilde{y} = y + r \cdot d + I^{h' > s} \left[(1 - \tau^{ll}) \cdot p^s(s - h')\right] \quad (2.6)$$

$$m' \leq (1 - \theta) p^h h' \quad (2.7)$$

$$m' \geq 0 \text{ and } d' \geq 0 \quad (2.8)$$

$$h' \geq s \quad \text{if } h' > 0. \quad (2.9)$$

Households from period $t = 1$ to 4 face the recursive problem above.[19] They enter the economy at $t = 1$ with zero assets and mortgage debt ($d = 0$, $h = 0$ and $m = 0$). Each period they earn (stochastic) labor income y, choose how much nondurable goods and housing services to consume, accumulate deposits and/or purchase housing. Labor income y is determined by the wage and total productivity of the household, i.e. $y = w \cdot e^{z_t^i + \varepsilon_t}$. In addition, at the end of each period, they receive transfers (T) from government, which are added to deposits of the next period. Households pay transaction costs whenever they change their house size (i.e. $h' \neq h$) and all homeowners pay maintenance costs. Landlords can deduct part (τ^{ll}) of their rental income from taxable income $\tilde{y}$ (eq.(2.6)). Mortgage debt cannot exceed the level implied by the down payment constraint (eq.(2.7)).

$$V_r(t, d, m, h) = \max_{c,s,d',m',h'} u(c, s) + (1 - I^{r4}) \cdot \beta E[V_r(t + 1, d', m', h')] + I^{r4} \cdot \phi(d', h') \tag{2.10}$$

subject to:

$$\begin{aligned} &c + p^s(s - h') + I^{h' \neq h} \cdot (\kappa^s p^h h + \kappa^p p^h h') + \delta_h \cdot p^h h' + I^{h' > s} \cdot \omega \\ &\leq b - [d' - (1 + r) \cdot d] + m' - (1 + r^m)m + p^h(h - h') - \left[\tau^y \tilde{y}_r + \tau^h p^h h'\right] \end{aligned} \tag{2.11}$$

$$\tilde{y}_r = b + r \cdot d - I^{h' > s} \tau^{ll} p^h (h' - s) \tag{2.12}$$

[19] I^{w4} is one when $t = 4$, I^w is one if households are workers and I^{ll} is one if households are landlords. An indicator function I^{w4} is used to separate the last working period ($t = 4$) from the rest since households at $t = 4$ consider the value function of retirees.

and eq. (2.7) $\sim$ (2.9).

The dynamic problem of retired households is similar to the problem of working households with a few exceptions: first, they receive pension b instead of labor income. Second, households die at the end of $t = 8$, and thus in that period they consider how much to leave as bequests.[20]

2.5 Stationary Equilibrium

Competitive Stationary Equilibrium Let x be a state vector (z, d, m, h) with individual state variables, let $\mathcal{S}$ be the state space supporting x, and let $\mathcal{B}_{\mathcal{S}}$ be the Borel σ-field. A stationary competitive equilibrium consists of value functions V^w and V^r, prices $\{p^h, p^s, r, w\}$ government policies $\{\tau^y, \tau^h, b, T\}$, policy functions, allocations, and a stationary distribution over x such that

1. Given prices, government policies, and the distribution of x, $c(x)$, $s(x)$, $h'(x)$, $d'(x)$ and $m'(x)$ solve the household maximization problems.

2. The representative firm maximizes profit:

$$r = F_1(K,\, L) - \delta \tag{2.13}$$

$$w = F_2(K,\, L). \tag{2.14}$$

[20]Note that I separate the last period from the rest in eq.(2.7) using an indicator function I^{r4}, which is one at $t = 8$ and zero otherwise. The bequest utility function is given by eq.(2.2).

3. The government policies satisfy:[21]

$$\int_{I^w=1} T \,\mathrm{d}\lambda = \int_{I^{r4}=1} q(x) \,\mathrm{d}\lambda \tag{2.15}$$

$$\begin{aligned} G + \int_{I^w=0} b \,\mathrm{d}\lambda = \tau^y \Big(y + \int_{I^w=0} b \,\mathrm{d}\lambda + \int_{I^{h'>s}=1} \Big((1-\tau^{ll}) \cdot p^s (h'(x) - s(x)) \Big) \mathrm{d}\lambda \Big) \\ + \tau^h \int_s p^h h'(x) \,\mathrm{d}\lambda \end{aligned} \tag{2.16}$$

4. All markets clear:[22]

$$D = M + K, \tag{2.17}$$

$$H = H^s, \tag{2.18}$$

$$S = H^s, \tag{2.19}$$

$$C + I_K + I_H + G + \Gamma = Y. \tag{2.20}$$

Note that aggregate variables are denoted with capital letters: D, M, H, S and C represent aggregate deposits, mortgage debt, housing demand, housing service consumption and consumption respectively. They are aggregates of individual-level allocations, e.g. $D = \int_S d'(x) \,\mathrm{d}\lambda$. Γ is aggregate transaction costs, while I_K and I_H denote aggregate investment in (nonresidential) capital and housing stock. Note that I assume housing stock H^s is fixed.[23]

[21] G represents government expenditure.

[22] Refer to Appendix B.1 for a solution algorithm.

[23] $I_K \equiv \delta K$, $I_H \equiv \delta_h q H$, and $\Gamma = \int_{Sell} \kappa^s q h(x)\, d\lambda(x) + \int_{Buy} \kappa^p q h'(x)\, d\lambda(x) + \int_{LL} \omega d\lambda(x) + \iota M$, where *Sell* and *Buy* represent selling households and purchasing households.

2.6 Calibration

Parameter		Value	Parameter		Value
AR(1) coefficient	ρ_z	0.90	Risk aversion (consumption)	γ_1	3.0
Innovation of prod.	σ_z^2	0.55	Risk aversion (housing)	γ_2	1.5
Age Efficiency Unit	ε_t	see text	Utility Discount for Renter	ψ	0.3
Selling cost	κ^s	0.07	Mortgage spread	ι	0.70%
Purchasing cost	κ^p	0.025	Rental Depreciation Rate	τ^{ll}	0.5
Maintenance Cost	δ_h	0.015	Property tax rate	τ^h	0.0013
Depreciation Rate (K)	δ	0.097	Down-payment ratio	θ	0.2
Capital Income Share	α	0.26			

Note: All parameters are calibrated to match annual data moments respectively.

Table 2.4: Externally Calibrated Parameters

In this section, I discuss the calibrated parameters that are used in this paper. As in Cho [2010], I take the earnings persistence level ρ_z from De Nardi [2004] and choose variance σ_z^2 to match the Gini coefficient for the average earnings of working households (age 20 to 59) from the recent Korean Labor and Income Panel Study (KLIPS) data from 2010 to 2017 (waves 13 to 20).[24] I use Tauchen and Hussey [1991] to discretize the income process into a four-state Markov chain. I report the productivity level and transition matrix in Appendix B.2. The age-dependent average earnings profile ε_t is calibrated using the average earnings profile from the same KLIPS data following Cho [2010].[25]

I assume separate relatve risk aversion parameters for nonhousing consumption (γ_1) and housing services (γ_2), and use the values from Cho [2012]. I fix the utility

[24] The legal retirement age in Korea is 60 years old.

[25] I calculate the average earnings for each age bin starting from age 20 to age 89 by 10 year intervals.

discount rate for rental housing ψ as 0.3 as in Cho [2012] and Mnasri [2015]. I use the selling and purchasing transaction cost parameters estimated by Gruber and Martin [2003], which are frequently used in the literature. The maintenance cost parameter δ_h is set to 0.015, following Díaz and Luengo-Prado [2010].

For the mortgage spread, I compare constant maturity rates of Korean government bonds and mortgage loans and choose 0.7%.[26] The deduction rate for rental income is a unique deduction for homeowners in Korea, and the actual rate ranges from 20% to 75% depending on the number and unit size of rental housing. I assume that 50% of rental income is deducted from income taxation in my model. The property tax rate on housing in Korea is among the lowest in the OECD, and its effective rate is 0.13%. I use this tax rate as a benchmark property tax rate on housing. Down payment ratio θ is set at 0.5, reflecting lower average loan-to-value (LTV) ratios in Korea than in other OECD countries.[27] To estimate the capital depreciation rate and capital income share, I use Korean National Accounts data from 2000 to 2018. I match data for private nonresidential assets to capital K and private residential assets for housing stock H.

Seven moments are jointly chosen internally to match a given set of aggregate targets. First, the nonresidential capital to output ratio (K/Y in the model), com-

[26] The Korean government bond constant maturity rate is used as a proxy for the interest rate on deposits, and a constant maturity "Bogeumjari Loan" rate provided by the Korean Housing Finance Corporation is used as a proxy for the mortgage loan rate. The spread ranges from 0.60% to 0.74%, depending on whether the mortgage maturity is 10 years, 20 years or 30 years. All data are average rates from 2014 to 2019.

[27] Kim et al. [2018] estimated the LTV ratio using 225,809 fixed-rate mortgage loans issued between 2004 and 2009. The loan-to-value (LTV) ratio ranges from 30 to 70% and the average LTV ratio is 57.48%. In comparison, Cho [2010] and Cho [2012] use even higher down payment ratios of 0.8 and 0.75, respectively.

Parameter		Value	Moment	Model	Data
Discount Factor	β	0.951	Capital / Output	2.350	2.350
Bequest Motive	ϕ_1	-8.259	Bequest / Wealth	0.50%	0.70%
Bequest Utility Shifter	ϕ_2	0.076	90th perc. of Bequest / Income	4.173	4.340
Income Tax Rate	τ^y	0.393	Gov. spending / Output	15.0%	15.0%
Consumption Share	η	0.780	Housing / Consumption	0.190	0.290
Fixed Cost (Landlords)	ω	0.005	Landlord / Homeowner	0.042	0.044
House Supply	H^s	0.800	Homeownership Rate	60.9%	60.0%

Table 2.5: Internally Calibrated Parameters

puted using the National Accounts data of Korea from 2000 to 2018, is matched using the discount factor parameter β. The total level of bequests in the economy is matched by calibrating the two bequest utility parameters ϕ_1 and ϕ_2 to the average bequest to wealth ratio and the 90th percentile of the bequest distribution normalized by income. Cho [2010] estimates the bequest to wealth ratio of Korea as 0.7%, which is lower than the ratio in the United States (0.88%, Gale and Scholz 1994). As reliable data for the distribution of bequests in Korea is not available, I borrow the 90th percentile of the bequest distribution normalized by income in the U.S. from [De Nardi and Yang, 2016]. Income tax rate τ^y is calibrated to match the government expenditure to output ratio, while the consumption share η is calibrated to match the ratio of personal expenditure on housing services to nonhousing consumption goods, all measured using the National Accounts data of Korea. According to the report by the Bank of Korea on the 2018 Survey of Household Finances and Living Conditions, the homeownership rate is 60% and the ratio of landlords to homeowners is 0.14. I use these values to discipline the fixed cost ω and the housing stock H^s.[28]

[28]Please refer to http://kostat.go.kr/portal/eng/surveyOutline/6/2/index.static for more details

2.7 Benchmark Results

In this section, I present results for the benchmark model simulation for the Korean economy. Table 2.6 compares non-targeted aggregate statistics between the model economy and the data.[29] While the model economy matches the ratio of financial assets to output well, households in the model economy hold more housing and less mortgage debt compared to the data.

	Data	Model
Homeowners in Debt (%)	26.4	17.6
Financial Asset to Output ratio (D/Y)	2.49	2.30
Housing Stock to Output ratio (H/Y)	0.86	1.38

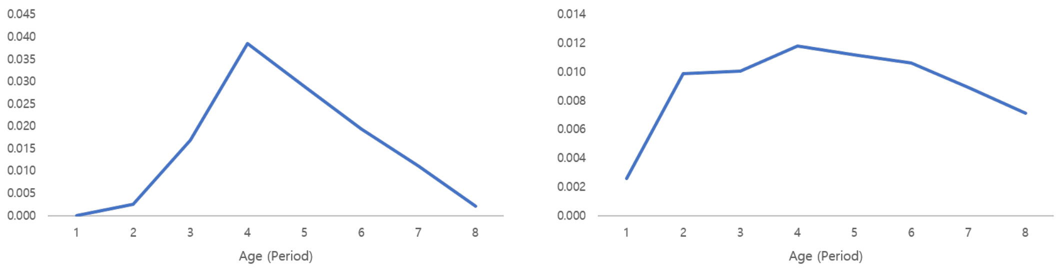
Table 2.6: Aggregate Statistics for Benchmark Model

Figure 2.3 displays the model profile of aggregate deposits and housing stock by household age. One can notice that both assets display a standard hump-shaped pattern over the lifecycle, which peaks at the last working period ($t = 4$). In addition, households decumulate housing stock more slowly than deposits over the lifecycle. These two features are consistent with the data patterns reported in Cho [2010].

Next, I compare the wealth distribution estimated from the Survey of Household Finances and Living Conditions 2010 - 2018 with the model simulated wealth distribution. From Table 2.7, one can notice that my model exhibits a wealth distribution similar to the distribution of wealth observed in Korea in the early 2010s,

on the Survey of Household Finances and Living Conditions.

[29]Statistics for households in debt are from the Housing Finance Statistics Report issued by the Korea Housing Corporation, and the other statistics are computed from the National Accounts data of Korea from 2000 to 2018.



(a) Lifecycle Holdings of Deposit (b) Lifecycle Holdings of Housing

Figure 2.3: Lifecycle Profile of Deposit and Housing Stock

particularly as measured by the Wealth Gini index (0.63 vs. 0.59∼0.63), although the model fails to reproduce the high share of total wealth held by the top 10 percentile in Korea. Note also that both the wealth Gini and the share of wealth held by the top 10 % wealthy households have fallen in recent years in Korea, suggesting declining wealth inequality, in contrast to the rising wealth inequality observed in many OECD countries.

Wave	Percentile					Gini
	60	40	30	20	10	
Data						
2010	95.4	85.1	76.8	65.1	47.2	0.628
2011	95.5	84.8	76.0	63.9	46.1	0.619
2012	94.8	84.2	75.6	63.8	46.2	0.616
2013	94.6	83.5	74.6	62.4	44.7	0.605
2014	94.1	82.7	73.8	61.5	43.7	0.596
2015	94.0	82.3	73.2	60.8	42.9	0.590
2016	94.1	82.1	72.8	60.2	42.1	0.585
2017	94.1	82.1	72.7	60.0	41.8	0.584
2018	94.2	82.3	73.1	60.5	42.3	0.588
Model						
	97.38	87.46	77.49	62.61	40.34	0.6259

Source: Survey of Household Finances and Living Conditions (2010∼2018)

Table 2.7: Total Wealth held by Households in the Top Percentile (%)

2.8 Policy Experiments

In the benchmark economy, the government applies a uniform property tax rate on all housing. In this section, I introduce a second tax rate for homeowners who own a large stock of housing, which reflects the observed heavy taxation on multiple home owners in Korea as discussed in Section 2.2. I assume that the amount of housing held by homeowners is a proxy for the number of housing units owned, and thus I use the term ”small housing” when households own a small number of housing units and ”large housing” when households own a large number of housing units. Accordingly, I set a lower property tax rate for ”small housing” and a higher property tax rate for ”large housing”. I assume that the lowest three grid points are considered as small homes and the rest as large homes (h'). First, I investigate a property tax scheme which separates small home owners and large home owners. Second, as an extension of the first experiment, I compare the equilibria in which 1) the uniform property tax rate is doubled, 2) only the property tax rate for large housing is doubled, 3) only the property tax rate for large housing is tripled.

Note that throughout the experiments, I assume that tax revenue that exceeds the government consumption and pension spending is treated as excess tax revenue and redistributed to all the households.[30] The idea is to control unintended effects on the consumption of households and have a fair welfare comparison, since without this redistribution, households would be worse off after all the tax revisions that weakly increase tax rates for everyone.[31]

[30] Bequests are still fully taxed and redistributed to workers.

[31] Note that having an additional lumpsum transfer does not change the results much, compared

2.8.1 Experiment 1: Dual Tax Rates

The new tax scheme consists of a lower tax rate τ_s^h for small housing and a higher tax rate τ_l^h for large housing. Two alternative sets of tax rates (τ_s^h, τ_l^h) are considered: {(Exp 1-1), (Exp 1-2)} = {(0.1%, 0.17%), (0.025%, 0.28%)}.[32] The tax rates are chosen as follows: first, I assume that the Korean government changes its tax regime without changing total tax revenue in the initial steady state. Given that limitation, I set the lower tax rate to be smaller than the current rate (from 0.13% to 0.1% or 0.025%), and then calculate the higher tax rate that yields the same total tax revenue based on the benchmark model's housing distribution.[33]

	Price				Asset		
	House Price	Rent	Interest Rate	$\frac{p^h}{p^s}$	Deposit	Housing	D/H
Benchmark	9.069	0.8526	3.9056%	10.64	0.119	0.07255	1.640
Exp 1-1	9.073	0.8533	3.9055%	10.63	0.120	0.07259	1.654
Exp 1-2	9.078	0.8546	3.9046%	10.62	0.120	0.07264	1.653

Note: Benchmark: $\tau^h = 0.13\%$, Exp 1-1: $(\tau_s^h, \tau_l^h) = (0.1\%, 0.17\%)$, Exp 1-2: $(\tau_s^h, \tau_l^h) = (0.025\%, 0.28\%)$

Table 2.8: Aggregate Effects of the Property Tax Change

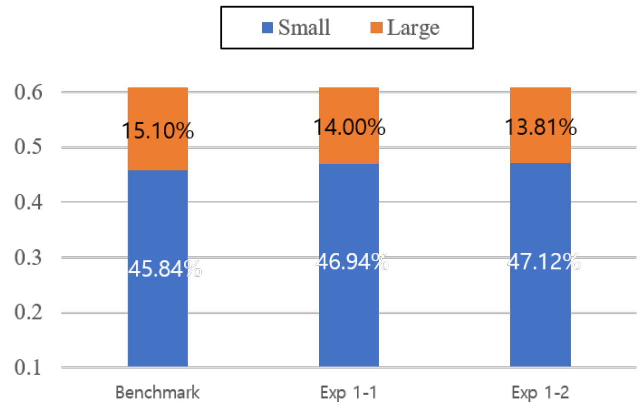
As the tax scheme is altered, current homeowners who hold large housing now face a higher property tax rate, while the rest of the households enjoy a lower property tax rate. The asymmetry in the property tax rate attracts households to demand less housing, and as a result, households downsize their house sizes, and fewer people are landlords. Figure 2.4 shows the shares of the population

with the experiments without the lumpsum transfer (the difference is very small).

[32]I use "Exp" as an abbreviation of a policy experiment hereafter.

[33]In practice, government could consider other factors such as the housing price elasticity. In addition, as the new tax schemes are in effect, tax revenue can be different in the new equilibrium due to changes in housing choices.

owning small and large housing in each experiment, and one can notice that as the asymmetry in property tax rate increases (from the benchmark to Exp 1-2), the share of households who hold small housing increases from 45.84% to 47.12%.



Note: Figures represent population shares and the numbers add up to homeownership rate.

Figure 2.4: Change in Housing Distribution (Exp-1)

At the same time, as lower tax rates induce marginal renters with less wealth to become homeowners, the homeownership rate rises, as does total demand for owned housing. As a result of excess demand in both markets, the housing price and rent increase. The rent increase reveals that the decreased number of landlords dominates the decreased number of renters. The lower interest rate is a reflection of resource reallocation from housing to deposits (refer to "D/H" in Table 2.8).

	Homeowner (A)	Landlord (B)	Renter	B / A
Benchmark	60.934	2.630	39.066	0.04317
Exp 1-1	60.935	2.616	39.065	0.04293
Exp 1-2	60.938	2.615	39.062	0.04292

Note: Exp 1-1: $(\tau_s^h, \tau_l^h) = (0.1\%, 0.17\%)$, Exp 1-2: $(\tau_s^h, \tau_l^h) = (0.025\%, 0.28\%)$

Table 2.9: Change in Housing Tenure (%)

At the new steady-state equilibrium in both sub-experiments ("Exp 1-1" and

”Exp 1-2”), the level of wealth inequality falls, as measured by the Gini index shown in Table 2.10. One can also note from Table 2.10 that the top 10 and 20 percentile households now hold less wealth, which suggests that punitive taxation on large housing transfers wealth from the wealthy to the poor.[34]

	Percentile					Gini
	60	40	30	20	10	
Benchmark	0.9738	0.8747	0.7748	0.6262	0.4034	0.6259
Exp 1-1	0.9738	0.8745	0.7748	0.6257	0.4027	0.6258
Exp 1-2	0.9738	0.8744	0.7747	0.6255	0.4025	0.6256

Note: (τ_s^h, τ_l^h) Exp 1-1: (0.1%,0.17%), Exp 1-2: (0.025%,0.28%)
Numbers in the percentile columns show the percentage of total wealth held by households in the top percentiles.

Table 2.10: Change in the Wealth Distribution

In addition to the distributional changes, I report the changes in social welfare induced by each tax experiment, using the expected utility of new born agents as the social welfare function. In Table 2.11, social welfare improves in both tax schemes, and increases more when the higher tax rate is increased (from +0.09% to +0.10%). Thus, one can conclude that the new tax schemes improve social welfare.

Overall, changes in the property tax scheme that penalize large home owners make the wealth distribution more equal. Table 2.12 shows changes in output and consumption in both experiments. Even though output and consumption of the economy increase, consumption of households in the top 25% of the wealth dis-

[34] I run an alternative, but similar tax scheme that sets a low property tax rate on owner-occupiers and a high property tax rate on landlords. The idea is that as landlords are multiple home owners by definition, distinguishing landlords from owner-occupiers in property taxation would fit the intended policy experiment. However, the mass of landlords in the benchmark model is in the largest housing grid point and therefore the analysis is limited. In addition, this alternative tax scheme does not perfectly reflect the actual policy in Korea, e.g. owner-occupiers can also have multiple homes. The results of this alternative experiment are qualitatively similar to the current experiment.

Benchmark	Exp 1-1	Exp 1-2
1	+ 0.09%	+ 0.10%

Note: This table shows the percentage change in social welfare relative to the benchmark economy under each alternative tax schemes.

Table 2.11: Change in Social Welfare

tribution falls in all experiments. This suggests that the alternative tax schemes redistribute wealth from the wealthy households to the poor households, which reduces the welfare of the wealthy households (as measured by their consumption level). If I further include heterogeneous asset returns or entrepreneurial productivity of households in the model, the welfare of the economy could be further reduced under the alternative tax schemes, as the wealthy would invest less. In this sense, I argue that one should be careful to interpret these results as justifying the Korean tax scheme.[35]

	Output	Consumption				
		Total	Q1	Q2	Q3	Q4
Benchmark	0.520952	0.35130	0.25545	0.27088	0.34748	0.53138
Exp 1-1	0.520954	0.35151	0.25554	0.27037	0.34894	0.53119
Exp 1-2	0.520975	0.35154	0.25682	0.26908	0.34899	0.53125

Note: Q1∼Q4 denote households in corresponding wealth quartile bins: e.g. Q1 represents the bottom 25% households in wealth.

Table 2.12: Change in Aggregate Output and Consumption

[35] One can argue that the Korean property tax scheme is improving the wealth distribution. However, one cannot argue that it is an "efficient" policy tool to achieve an equal wealth distribution in Korea or a welfare improving tax policy.

2.8.2 Experiment 2: Increased Tax Rates, Single vs. Dual

A series of property tax revisions have recently been adopted by the Korean government that increase tax rates on all housing, but more drastically on multiple home owners' properties. In line with the announced plan, I consider introducing the following set of tax rates to the model economy: (Exp 2-1), (Exp 2-2), (Exp 2-3) = {(0.26%), (0.13%, 0.26%), (0.13%, 0.39%)}. In short, the first tax experiment doubles the current property tax rate, the second experiment doubles the property tax rate only on large size housing and the third experiment triples the property tax rate only on large size housing.

	Price					Asset	
	House Price	Rent	Interest Rate	p^h/p^s	Deposit	Housing	D/H
Benchmark	9.069	0.8526	3.9056%	10.64	0.1190	0.0726	1.6402
Exp 2-1	9.054	0.8531	3.9031%	10.61	0.1195	0.0724	1.6501
Exp 2-2	9.060	0.8544	3.9086%	10.60	0.1200	0.0725	1.6553
Exp 2-3	9.062	0.8559	3.9042%	10.59	0.1200	0.0725	1.6550

Note: (τ_s^h, τ_l^h): Exp 2-1: 0.26 (single rate), Exp 2-2: (0.13%,0.26%), Exp 2-3: (0.13%,0.39%)

Table 2.13: Aggegate Effects of the Property Tax Change

As the tax rate is doubled (Exp 2-1), owning a house now requires more tax payment, and consequently housing demand and the housing price fall (the homeownership rate falls from "Benchmark" to "Exp 2-1" in Table 2.14). The lower housing price attracts homeowners to increase housing size, leading to more landlords in the new equilibrium. (Figure 2.5). On the other hand, if the government doubles the property tax rate only for large housing (Exp 2-2), the total homeownership rate increases (compare "Exp 2-2" with "Benchmark"), while the number

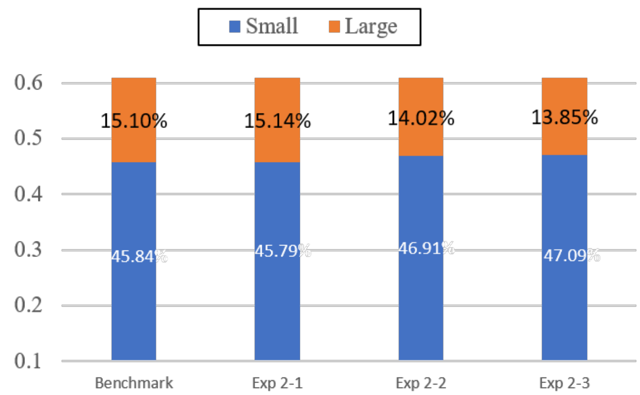


Figure 2.5: Change in Housing Distribution (Exp-2)

of landlords falls relative to the benchmark. This is because asymmetric tax rates attract more households to own small housing (1.8%p increase in small housing). As the overall housing demand is concentrated on small housing, the housing price falls by less than in ”Exp 2-1”, and the fall in rental supply causes rents to increase (Table 2.13). Finally, if the government further increases the property tax rate on large size housing (Exp 2-3), the same qualitative changes to asset allocation, price variables and housing tenure occur as in ”Exp 2-2”.

	Homeowner (A)	Landlord (B)	Renter	B / A
Benchmark	60.9345	2.630	39.066	0.0432
Exp 2-1	60.9343	2.634	39.066	0.0432
Exp 2-2	60.9371	2.619	39.063	0.0430
Exp 2-3	60.9373	2.619	39.063	0.0430

Note: (τ_s^h, τ_l^h): Exp 2-1: 0.26, Exp 2-2: (0.13%,0.26%), Exp 2-3: (0.13%,0.39%)

Table 2.14: Change in Housing Tenure (%)

In terms of the wealth distribution, the level of inequality increases by a small amount in ”Exp 2-1”, due to a general increase in property tax rate (refer to Table 2.15).[36] However, introducing a second property tax rate helps to decrease wealth

[36] Since the property tax is proportional, not progressive, the overall increase in the tax rate

inequality, as the wealth Gini falls if we transit from "Exp 2-1" to "Exp 2-2" and "Exp 2-3".[37]

	Percentile					Gini
	60	40	30	20	10	
Benchmark	0.9738	0.8747	0.7748	0.6262	0.4034	0.62592
Exp 2-1	0.9739	0.8748	0.7749	0.6263	0.4035	0.62603
Exp 2-2	0.9739	0.8745	0.7750	0.6259	0.4029	0.62591
Exp 2-3	0.9739	0.8745	0.7749	0.6258	0.4027	0.62579

Note: (τ_s^h, τ_l^h): Exp 2-1: 0.26 (single rate), Exp 2-2: (0.13%,0.26%), Exp 2-3: (0.13%,0.39%). Numbers in percentile column mean the percentage of total wealth held by households in the top percentiles.

Table 2.15: Change in the Wealth Distribution

Note that this decrease in wealth inequality comes with a fall in consumption of wealthy households in the top 25%, who hold large housing as in Subsection 2.8.1. Overall social welfare increases in all experiments, and increases the most in "Exp 2-3" in Table 2.17.

	Output	Consumption				
		Total	Q1	Q2	Q3	Q4
Benchmark	0.52095	0.35130	0.25545	0.27088	0.34748	0.53138
Exp 2-1	0.52101	0.35131	0.25553	0.27110	0.34732	0.53128
Exp 2-2	0.52088	0.35153	0.25555	0.27047	0.34885	0.53124
Exp 2-3	0.52098	0.35153	0.25562	0.27049	0.34883	0.53119

Note: Q1∼Q4 denote households in corresponding wealth quartile bins: e.g. Q1 represents the bottom 25% households in wealth.

Table 2.16: Change in Aggregate Output and Consumption

Lastly, I investigate alternative tax schemes in which the income tax rates are adjusted (lowered) to compensate for the increased property tax rates in the second

increases wealth inequality in the model.

[37]Comparing "Exp 2-2" and "Exp 2-3" is the clearest way to make this argument, since they both have the same tax rate for small housing unlike the comparison of "Exp 2-1" to "Exp 2-2".

Benchmark	Exp 2-1	Exp 2-2	Exp 2-3
1	+0.11%	+0.10%	+0.14%

Note: This table shows the percentage change in social welfare relative to the benchmark economy under each alternative tax schemes.

Table 2.17: Change in social Welfare

set of experiments. Results are qualitatively the same, except that the lowered income tax rate further decreases wealth inequality (I report the relevant tables in Appendix B.3).

2.9 Conclusion

In this paper, I study the effects on the wealth distribution of a recent Korean property tax scheme that penalizes multiple home owners with higher tax rates, using a dynamic lifecycle model. My model shows that the tax scheme decreases wealth inequality, yet the magnitude of the impact is small. Although the policy improves the wealth inequality of Korea, I hesitate to call it an efficient policy tool, in consideration of potential opportunity costs and welfare losses.

Since this paper is the first to analyze the distributional effects of the Korean housing property tax system theoretically, more features can be added to the model in subsequent work. As this paper is part of the literature that studies the wealth distribution, having a model that can generate a more rich and realistic wealth distribution is crucial. In that sense, stochastic asset returns, both on deposits and housing stock, can be considered. Lastly, the capital gains tax that is incurred when selling housing in Korea also discriminates against multiple home owners. Therefore, analyzing the distributional effects of the capital gains tax can be worthwhile as well.

Appendices

A.1 Goods Market Clearing

In this Section, I show that the steady state equilibrium condition for the goods market can be derived from individual agents' optimal decisions and other markets' equilibrium conditions. In a sense, I prove that Walras' law holds in the model. Per-capita, individual-level variables are denoted as $x_t \equiv X_t$, where $X_t \in \{C_t, S_t, D_t, K_t, M_t,\ H_t, G_t, Y_t\}$ denote aggregate variables.[38]

There is some different notation used in this Section. Every variable with subscript wl stands for working landlords, wo for working homeowners, wr for working renters, rl for retired landlords, ro for retired homeowners, rr for retired renters. Furthermore, aggregate variables are written in corresponding capital letters. One needs to recall that the timing convention for residential assets is different in the individual agent's decision as h' is a decision at the beginning of the period. However, I denote the aggregate variable H using the same timing convention as the other state variables to avoid confusion: i.e., H is total (aggregate) residentials asset for this period.

Now, consider a working landlord making her choices of consumption c and s, assets d' and h', and mortgage debt m'. One can easily show how her budget

[38]Note that the model economy has no growth.

constraint can be rearranged at the steady-state equilibrium as follows:

$$
\begin{aligned}
c_{wl} = {} & (1-\tau^y)\left[wl_{wl} + rd_{wl} + \rho(h'_{wl} - s_{wl}) - \tau^h q h'_{wl} - \delta_h q(h'_{wl} - s_{wl})\right] \\
& - (1-\tau^y\tau^m) r^m m_{wl} - \omega + \tau^y \tau^{ll} q(h'_{wl} - s_{wl}) - \delta_h q s_{wl} - [I^s \kappa^s q h_{wl} + I^p \kappa^p q h'_{wl}] \\
& - [(d'_{wl} - d_{wl}) + q(h'_{wl} - h_{wl}) - (m'_{wl} - m_{wl})]
\end{aligned}
$$

The first three terms on the first line are labor earnings, interest from financial assets, and rental income from houses net of income taxes respectively. The last two terms on the first line of the equation are property tax, and maintenance costs on rental houses. The second line shows mortgage loan payment net of deductions, the fixed transaction cost of landlords, deductions for depreciation of tenant-occupied houses, maintenance costs for her own house, and individual transaction costs. The last line of the equation shows the changes in the levels of financial assets, residential assets, and mortgage debt. I changed the notation for transaction costs to I^x to save notation, where $x \in \{s, p\}$ states the situation of selling and purchasing housing respectively.

A working homeowner's budget constraint at the steady-state is

$$
\begin{aligned}
c_{wo} = {} & (1-\tau^y)\left[wl_{wo} + rd_{wo} - \tau^h q h'_{wo} + b_{wo}\right] - (1-\tau^y\tau) r^m m_{wo} - \delta_h q s_{wo} \\
& - [I^s \kappa^s q h_{wo} + I^p \kappa^p q h'_{wo}] - [(d'_{wo} - d_{wo}) + q(h'_{wo} - h_{wo}) - (m'_{wo} - m_{wo})] .
\end{aligned}
$$

Notice that incomes and deductions for landlords disappear from this equation, and further that $\rho(s_{wo} - h'_{wo})$ is removed as $s_{wo} = h'_{wo}$.

A working tenant-occupier or renter's budget constraint at the steady state is:

$$c_{wr} = (1-\tau^y)\left[wl_{wr} + rd_{wr} + b_{wr}\right] - \rho s_{wr} - \left[(d'_{wr} - d_{wr}) - qh_{wr} + m_{wr}\right].$$

Similarly, budget constraints for retirees with different tenure choice can be summarized as the following three equations at the steady state:

$$\begin{aligned}
c_{rl} &= (1-\tau^y)\Big[tr + rd_{rl} + \rho(h'_{rl} - s_{rl}) - \tau^h q h'_{rl} - \delta_h q(h'_{rl} - s_{rl})\Big] \\
&\quad - (1-\tau^y\tau^m)r^m m_{rl} - \omega + \tau^y\tau^{ll} q(h'_{rl} - s_{rl}) - \delta_h q s_{rl} - \left[I^s\kappa^s q h_{rl} + I^p\kappa^p q h'_{rl}\right] \\
&\quad - \left[(d'_{rl} - d_{rl}) + q(h'_{rl} - h_{rl}) - (m'_{rl} - m_{rl})\right], \\
c_{ro} &= (1-\tau^y)\Big[tr + rd_{ro} - \tau^h q h'_{ro}\Big] - (1-\tau^y\tau^m)r^m m_{ro} - \delta_h q s_{ro} \\
&\quad - \left[I^s\kappa^s q h_{rl} + I^p\kappa^p q h'_{rl}\right] - \left[(d'_{ro} - d_{ro}) + q(h'_{ro} - h_{ro}) - (m'_{ro} - m_{ro})\right], \text{ and} \\
c_{rr} &= (1-\tau^y)\left[tr + rd_{rr}\right] - \rho s_{rr} - \left[(d'_{rr} - d_{rr}) - qh_{rr} + m_{rr})\right].
\end{aligned}$$

Note that social security income tr replaces labor income in the retiree's budget constraint. Now, aggregating the budget constraints of all agents in the economy gives the following equation:

$$\begin{aligned}
C &= wL_W + PENS \\
&\quad - \tau^y(wL_W + rK + PENS + \rho(s_{wr} + s_{rr}) - \tau^h qH - \tau^m rM - \tau^{ll} q(h'_{wl} + h'_{rl} - s_{wl} - s_{rl}) \\
&\quad - \tau^h qH - \delta_h q(h'_{wl} + h'_{rl} - s_{wl} - s_{rl}) - \delta_h q(s_{wl} + s_{wo} + s_{rl} + s_{ro}) \\
&\quad - rD - r^m M - TRANS,
\end{aligned}$$

where[39]

$$
\begin{aligned}
C &= \int_S \left(c_{wl}(x) + c_{wo}(x) + c_{wr}(x)\right)\, d\lambda(x) \\
L_W &= \int_S \left(l_{wl}(x) + l_{wo}(x) + l_{wr}(x)\right)\, d\lambda(x) \\
L &= L_W + L_R \\
PENS &= tr \cdot L_R \\
D &= \int_S \left(d_{wl}(x) + d_{wo}(x) + d_{wr}(x) + d_{rl}(x) + d_{ro}(x) + d_{rr}(x)\right)\, d\lambda(x) \\
M &= \int_S \left(m_{wl}(x) + m_{wo}(x) + m_{rl}(x) + m_{ro}(x) + m_{wr}(x) + m_{rr}(x)\right)\, d\lambda(x) \\
TRANS &= \int_S \left(I^s \kappa^s q(h_{rl}(x) + h_{ro}(x)) + I^p \kappa^p q(h'_{rl}(x) + h'_{ro}(x))\right)\, d\lambda(x) + \int_{Landlord} \omega d\lambda(x).
\end{aligned}
$$

The first line of the first equation above is total income of all agents, coming from the labor income wL_W and pensions $PENS$. Note that at the steady state equilibrium, the sum of landlords' rental incomes from houses $\rho(h'_{wl} + h'_{rl} - s_{wl} - s_{rl})$ cancels out the sum of renters' rental payments $\rho(s_{wr} + s_{rr})$.

The second line shows the income tax on the incomes stated in the first line, plus landlords' rental incomes from rental units, minus respective deductions for landlords and homeowners. The third line shows property taxes on total housing stocks and maintenance costs incurred to landlords and homeowners. The fourth line shows interest from financial assets D and interest payments on mortgage debt M, and total transaction costs $TRANS$.

As the financial intermediary's budget is balanced, $rD - r^m M$ in the fifth line

[39] L is the number of total population which consists of labor force L_W and retiree L_R. Note that I leave population growth rate variable n in the equation.

turns into $rK - \iota M$. I combine this with labor income and get $wL_W + rK - \iota M$. Since the final goods firm in the competitive market has zero profit, this term can now be simplified to $F(K,L) - \delta K - \iota M$.

$$
\begin{aligned}
C &= F(K,L) + PENS - \delta K - \iota M \\
&\quad - \tau^y \left[F(K,L) - \delta K + PENS + \rho S_R - \tau^h qH - \tau^m rM - \tau^{ll} q(H_{LL} - S_{LL}) - \delta_h q(H_{LL} - S_{LL})\right] \\
&\quad - \tau^h qH - \delta_h q(H_{LL} + H_O) - TRANS.
\end{aligned}
$$

The equation can be further simplified using aggregate residential asset and housing service consumption variables for landlords (LL), homeowners (O), and renters (R):

$$
\begin{aligned}
S &= S_{LL} + S_O + S_R = \int_S (s_{wl}(x) + s_{rl}(x))\ d\lambda(x) + \int_S (s_{wo}(x) + s_{ro}(x))\ d\lambda(x) \\
&\quad + \int_S (s_{wr}(x) + s_{rr}(x))\ d\lambda(x) \\
H &= H_{LL} + H_O = \int_S (h_{wl}(x) + h_{rl}(x))\ d\lambda(x) + \int_S (h_{wo}(x) + h_{ro}(x))\ d\lambda(x)
\end{aligned}
$$

Finally, the aggregate equilibrium condition for the goods market is the following:

$$
C + I_K + I_H + G + \Gamma = Y,
$$

where I_K denotes gross nonresidential investment, I_H denotes residential investment needed to keep housing stocks constant, G denotes government expenditure, and Γ

denotes transaction costs defined as below. [40]

$$
\begin{aligned}
I_K &= \delta K \\
I_H &= \delta_h q H \\
G &= T - PENS \\
\Gamma &= TRANS + \iota M,
\end{aligned}
$$

in which total tax revenue T and total deductions DED are defined as the following:

$$
\begin{aligned}
T &= \tau^y \left(Y - \delta K + PENS + \rho S_R\right) - DED + \tau^h q H + \tau^b \int_S \left(b_r(x) - x_b\right)\, d\lambda(x) \\
DED &= \tau^y \left(\tau^h q H + \tau^m r M + \tau^{ll} q (H_{LL} - S_{LL}) + \delta_h q (H_{LL} - S_{LL})\right).
\end{aligned}
$$

Note that bequests merge with financial assets in the second period and thus disappear from the final equation. To summarize, the goods market equilibrium condition is redundant due to Walras' law, which holds in this model.

A.2 Parameter in the Bequest Utility

In this Section, I refer to the online Appendix 1.6 of De Nardi and Yang [2016] and interpret the bequest utility function which follows their functional form. Two parameters ϕ_1 and ϕ_2 explicitly governs the agent's decision over the bequest to pass to the next generation at death. To better understand their role in bequest giving, consider an agent who starts the period with net worth x and dies for sure

[40] Residential investment is maintenance costs since housing supply is fixed in this model.

next period. In the model, $x \equiv qh + d - m$. The agent faces budget constraint $b_n = x - c - \rho s$, where b_n denotes the bequest, c nondurable consumption, s housing services, and ρ the rental price. The bequest level one considers to derive utility is the gross bequest net of estate tax (*net bequest*): $b_n = x'$ if $x' < x_b$ and $b_n = (1-\tau_b)(x' - x_b) + x_b$ if $x' \geq x_b$, where x' is net worth left after consuming $\mathbf{c}$ at the end of the period. I confine the following analysis to the interior solution.

The agent solves the following maximization problem:

$$\max \frac{\mathbf{c}^{1-\gamma}}{1-\gamma} + \phi_1 \left[(b_n + \phi_2)^{1-\gamma} - 1 \right]$$

$$s.t. \begin{cases} b_n = x - \mathbf{c} & \text{if } x' < x_b \\ b_n = (1-\tau_b)(x - \mathbf{c} - x_b) + x_b & \text{if } x' \geq x_b \end{cases}$$

where $\mathbf{c}$ is a vector of consumption baskets which consist of nondurable consumption and housing services. If $x' < x_b$, the first-order condition of the problem can be simplified to imply:

$$b_n = \frac{x - f_1 \phi_2}{1 + f_1},$$

$$\text{where } f_1 = (\phi_1(1-\gamma))^{-\frac{1}{\gamma}}.$$

If $x' \geq x_b$, we have:

$$b_n = \frac{(1-\tau_b)(x - x_b - \phi_2 f_2) + x_b}{1 + f_2(1-\tau_b)},$$
$$\text{where } f_2 = \left(\frac{\phi_1(1-\gamma)}{\gamma}\right)^{-\frac{1}{\gamma}}.$$

Now, one can interpret the equations above as follows: the optimal b_n in the equation is applicable only when x is large enough, otherwise the agent will not leave any bequest. Consequently, ϕ_2 governs the threshold wealth level such that the larger the level of ϕ_2 , the larger bequest b_n becomes. The marginal utility from bequests is affected by f_1 and f_2 follows:

$$\begin{cases} \frac{\partial}{\partial x} b_n = \frac{1}{1+f_1} & \text{if } x' < x_b \\ \frac{\partial}{\partial x} b_n = \frac{1-\tau_b}{1+f_1} & \text{if } x' \geq x_b \end{cases}.$$

Therefore, ϕ_1 can attract the agent to bequeath more by affecting the marginal utility from leaving bequests.

A.3 Computation Specification

A.3.1 Estimation of Capital Income Share

Recently, Gomme and Rupert [2007] have challenged the seminal work of Cooley and Prescott [1995] in the estimation of the capital income share. The two papers differ in their definition of capital stock: Gomme and Rupert [2007] implement a narrow measure of capital by excluding government capital and do not impute capital income to government, while Cooley and Prescott [1995] use a broad measure of capital including government capital and household capital, and impute capital income to government and household capital. I choose the narrow measure of capital by excluding government capital, but treat consumption durables as part of nonresidential capital unlike Gomme and Rupert [2007].[41] I separate nonresidential capital K and residential capital H to match the framework of my paper.

I define output Y as Gross Domestic Product (GDP) net of service flows from housing Y_H and labor income to government Y_{LG}. In this way, I can consider the existence of residential housing explicitly and can define Y as the sum of labor income and nonresidential capital income in the private sector.[42] Output Y is comprised of three parts: unambiguous private capital income Y_K, unambiguous private labor income Y_L, and ambiguous private income Y_A. Following the assumption of competitive factor markets, I assign the share of ambiguous private income to capital. Therefore, total private capital income is $Y_K + \alpha Y_A$. Consequently, I can estimate the capital share as follows: [43]

$$\alpha = \frac{Y_K}{Y - Y_A} = \frac{Y_K}{Y_K + Y_L}.$$

[41] Gomme and Rupert [2007] treat consumption durables as household capital.

[42] Ideally, it should be the case that GDP $= Y_{LH} + Y_{KH} + Y_{KP} + Y_{LP} + Y_{KG} + Y_{LG}$, where subscript L denotes labor income, K capital income, H house sector, P private sector where in the paper I omitted intentionally, G government sector. However, NIPA data do not have measures for capital income to government and therefore removing only labor income to government can carve out government sector from output of interest. In fact, this poor measurement of NIPA data is the main reason behind two different imputation methods introduced here.

[43] Please note that $Y = Y_K + Y_L + Y_A$.

In this way, I do not need to impute income flows from durables or government capital, unlike Cooley and Prescott [1995].

A.3.2 Estimation of Aggregate Variables

I define aggregate variables to be measured in NIPA and FAT data to be in line with the model structure. In terms of expenditure, output Y can be spent on nondurable consumption C, investment in nonresidential capital I_K, investment in residential capital I_H, and government spending G. The variable C is the sum of private consumption expenditures on nondurables and services excluding housing expenditures and government consumption expenditures. The variable I_K is the sum of private nonresidential fixed investment plus the change in private inventories, and I_H is residential fixed investment plus personal consumption expenditure on durables. The stock variable K includes private fixed nonresidential assets, private inventories, and the stock of consumer durables as discussed above, and H is private fixed residential assets and private inventories. Lastly, government spending G is government consumption expenditures as measured in the NIPA.

I compute the nonresidential capital stock depreciation rate following Gomme and Rupert [2007]. FAT data provides figures for both the capital stock and depreciation. The depreciation rate for capital x in year t is computed as depreciation of x in year t divided by the stock of structures as of the end of year $t-1$, or $\delta_t^x = \frac{\text{DEP}_t^x}{x_{t-1}}$. The downside of this method is that it slightly overestimates the depreciation rate since BEA treats investment over year t as occurring half way through the year.[44]

[44] In short, the depreciation rate for year t includes only 6 months of depreciation on investments

Variable	Estimation in NIPA and FAT
$\boldsymbol{Y}$	**Nominal private market output**: *Gross Domestic Product - Gross Housing Product - Government Compensation of Employees*
$\boldsymbol{Y_K}$	**Nominal private unambiguous capital income**: *(Rental Income + Net Interest Income + Corporate Profits) + (Gross National Product - Net National Product) - (Housing Rental Income + Housing Net* *Interest Income + Housing Corporate Profits) - (Housing Gross Value Added - Net Housing Value added)*
$\boldsymbol{Y_L}$	**Nominal private unambiguous labor income**: *Compensation of Employees- Housing Compensation of Employees*
$\boldsymbol{Y_A}$	**Nominal private ambiguous income**: *(Proprietors' Income - Housing Proprietors' Income)*
$\boldsymbol{I_K}$	**Nominal nonresidential investment**: *Fixed Investment + Change in Private Inventories + Personal Consumption Expenditures on Durables*
$\boldsymbol{I_H}$	**Nominal residential investment**: *Residential Fixed Investment*
$\boldsymbol{C}$	**Nominal nondurable consumption**: *Private consumption expenditures on nondurables and Services - Housing* *expenditures*
$\boldsymbol{K}$	**Nominal nonresidential capital**: *Private fixed nonresidential assets + Private Inventories + Consumer Durable Goods*
$\boldsymbol{H}$	**Nominal residential capital**: *Private fixed residential assets + Private inventories*
$\boldsymbol{G}$	**Nonminal government expenditure** : *Government consumption expenditures*

Table A.1: Data Description

A.4 Analytic Relationship of Market Prices

In this section, I analytically describe the relationship between market prices, i.e. housing price, rent price, and interest rate. Note that I remove time subscript t from prices since we study the steady-state equilibrium. The Recursive problem of homeowners is simplified to the following sequential problem with no transaction costs and bequest motives.

$$
\begin{aligned}
&\max \sum_{t=1}^{3} \beta^{t-1} u(c_t, s_t) \\
&s.t.\ c_t + \rho(s_t - h_{t+1}) + q(h_{t+1} - h_t) + d_{t+1} - m_{t+1} + MC_t \\
&\quad + \tau^y(INC_t + rd_t - \tau^m r^m m_t - \tau^h q h_{t+1} - Ded_t) \\
&\quad + \tau^h q h_{t+1} \leq INC_t + (1+r)d_t - (1+r^m)m_t \\
&m_{t+1} \leq (1-\theta) q h_{t+1}\, \forall t.
\end{aligned}
$$

I only consider an interior solution here and denote λ_t and γ_t as the shadow prices of the budget constraint and down payment regulation, MC_t as maintenance costs, INC_t as labor income and pension income, and Ded_t as deductions for landlords. Then the first order conditions are the following:

made in year t in BEA data.

$$
\begin{aligned}
c_t :& u_c(t) = \lambda_t \\
s_t :& u_s(t) = \lambda_t(\rho + \frac{\partial Ded_t}{\partial s_t}) \\
h_{t+1} :& \lambda_t(\rho - q + \frac{\partial MC_t}{\partial h_{t+1}} + \tau^y \frac{\partial Ded_t}{\partial h_{t+1}} - \tau^h(1-\tau^y)q + \gamma_t(1-\theta)q = -\beta\lambda_{t+1}q \\
d_{t+1} :& \lambda_t = \beta\lambda_{t+1}(1 + r - \tau^y r_{t+1}) \\
m_{t+1} :& \lambda_t - \gamma_t = \beta\lambda_{t+1}((1+r^m)\tau^y - \tau^m r^m)
\end{aligned}
$$

With further rearrangement of these conditions, one can obtain the following equations:

$$
\begin{aligned}
\frac{u_s(t)}{u_c(t)} &= \rho + \frac{\partial Ded_t}{\partial s_t} \\
\frac{\beta u_c(t+1)}{u_c(t)} &= -\frac{\rho - q + \frac{\partial MC_t}{\partial h_{t+1}} + \tau^y \frac{\partial Ded_t}{\partial h_{t+1}}}{q} + \tau^h(1-\tau^y) - \gamma_t(1-\theta) \\
\frac{\beta u_c(t+1)}{u_c(t)} &= \frac{1}{1 + r - \tau^y r} \\
u_c(t)(1 - \frac{(1+r^m)\tau^y - \tau^m r^m}{1 + r - \tau^y r}) &= \gamma_t
\end{aligned}
$$

Now one can derive the intertemporal euler equation:

$$\rho + \frac{\partial MC_t}{\partial h_{t+1}} + \tau^y \frac{\partial Ded_t}{\partial h_{t+1}} = q\left[1 - \frac{\beta u_c(t+1)}{u_c(t)}\right] + q\tau^h(1-\tau^y) - q\gamma_t(1-\theta)$$

$$\rho + \frac{\partial MC_t}{\partial h_{t+1}} + \tau^y \frac{\partial Ded_t}{\partial h_{t+1}} = q\left[1 - \frac{1}{1+r-\tau^y r} + \tau^h(1-\tau^y) - (1-\theta)u_c(t)(1 - \frac{(1+r^m)\tau^y - \tau^m r^m}{1+r-\tau^y r})\right]$$

$$\rho = q\left[\frac{(1-\tau^y)r - (1-\theta)u_c(t)(1+r-(1+r+r^m)\tau^y - \tau^m r^m)}{1+(1-\tau^y)r}\right] \tag{21}$$

$$+ q\tau^h(1-\tau^y) - \frac{\partial MC_t}{\partial h_{t+1}} - \tau^y \frac{\partial Ded_t}{\partial h_{t+1}}$$

When we replace $\frac{\partial MC_t}{\partial h_{t+1}} \equiv \delta_h q$ and $\frac{\partial Ded_t}{\partial h_{t+1}} \equiv \rho - \tau^{ll} q - \delta_h q$ (Note: δ_h is common depreciation rate for houses), we find:

$$\frac{\rho}{q} = \frac{1}{1+\tau^y} \times \{\frac{(1-\tau^y)r - (1-\theta)u_c(t)(1+r-(1+r+r^m)\tau^y - \tau^m r^m)}{1+(1-\tau^y)r} + \tau^h(1-\tau^y)$$

$$-\delta_h + \tau^y(\tau^{ll} + \delta_h)\}$$

Since the term inside the bracket is positive, one can see that the rent-to-price ratio will decrease (equivalently, the price-to-rent ratio increases) with a falling down payment ratio, if the interest rate does not change. This is consistent with the literature that reports increasing house price to rent ratios with financial deregulation under the partial equilibrium framework. However, since this paper considers a general equilibrium analysis, the direction of the change of the price-to-rent ratio can be different.

A.5 Labor Income Process

I adjust the transition matrices of De Nardi and Yang [2016] to fit into my model periods. I use their transition matrices for both earnings and productivity transfer between generations. Specifically, one model period in my model is 20 years, while their model uses 5 years. Therefore I assume these matrices hold during each model period, and multiply the matrices, and reconstruct the initial probability masses to be consistent with my model. The support for the productivity level distribution follows Castañeda et al. [2003] as in De Nardi and Yang [2016]:

The Transition Matrix for earnings process is

$$\begin{bmatrix} 0.5965 & 0.3158 & 0.0874 & 0.00030 \\ 0.3960 & 0.3860 & 0.2175 & 0.00049 \\ 0.2006 & 0.3961 & 0.4027 & 0.00057 \\ 0.2717 & 0.1360 & 0.1640 & 0.42837 \end{bmatrix}$$

Transition Matrix for intergenerational productivity transfer is

$$\begin{bmatrix} 0.8272 & 0.1704 & 0.0024 & 0.0000000000 \\ 0.5748 & 0.4056 & 0.0196 & 0.0000000000 \\ 0.2890 & 0.6173 & 0.0937 & 0.0000000005 \\ 0.0001 & 0.0387 & 0.9599 & 0.0012647506 \end{bmatrix}$$

and the initial distribution of earnings over the four productivity levels

$$\begin{bmatrix} 0.6689 & 0.3102 & 0.0209 & 0.0000005 \end{bmatrix}$$

B.1 Solution Algorithm

1. Make a i^{th} guess of the government transfer T_i and a j^{th} guess of the market clearing price vector: housing price q_j, rent price ρ_j, and interest rate r_j.

2. Search for the price values such that excess demand in each market is close to zero. I use three nested loops to find equilibrium price levels for the housing stock, housing services and the financial asset.

   (a) In each iteration, find the optimal policy functions that solve the corresponding Bellman equations by backwards induction starting from the last period.

   (b) With the policy functions from Step 2-(a), find a stationary distribution over the state space.

3. With the policy functions and invariant distributions from Step 2, check if all markets clear. If not satisfied, update the guess for the price vector and repeat the $j + 1^{th}$ iteration process. If satisfied, check if total government transfer is equal to aggregate bequests B. If all conditions are satisfied, a stationary equilibrium is found. If the i^{th} guess of the government transfer T_i does not balance the government budget, update the guess of government transfers and repeat the $i + 1^{th}$ iteration process.[45]

[45] The government budget constraint is balanced with flexible government consumption expenditure and the goods market clears by Walras' law.

B.2 Income Process

In this section, I report relevant figures for the estimated income process. I use Tauchen and Hussey [1991] to discretize the AR(1) income process to a four-state Markov process.

Productivity level

$$\left\{ \begin{matrix} 0.4701829 & 0.7867454 & 1.2710593 & 2.1268318 \end{matrix} \right\}$$

Transition matrix

$$\left\{ \begin{matrix} 0.7329819 & 0.2556624 & 0.0113154 & 0.0000403 \\ 0.1744868 & 0.5963896 & 0.221401 & 0.0077226 \\ 0.0077226 & 0.221401 & 0.5963896 & 0.1744868 \\ 0.0000403 & 0.0113154 & 0.2556624 & 0.7329819 \end{matrix} \right\}$$

The age efficiency unit profile is estimated using the Korean Labor and Income Panel Study (KLIPS) data from 2010 to 2017.

Age efficiency units:

$$\left\{ \begin{matrix} 1 & 1.6827577 & 1.9162517 & 1.8844634 \end{matrix} \right\}$$

The estimated income process targets the Gini index of Korea (0.35, OECD 2017).

	Data*	Model
Gini Index	0.35	0.33

∗ Source: OECD Social and Welfare Statistics: Income distribution

Table B.1: Income Gini Index

B.3 Addendum to the Experiment 2

In this section, I show model outcomes from additional experiments as an extension of Experiment 2 in Section 2.8.2: i.e. the government lowers income tax rates to compensate for the increased property tax rates as in Experiment 2. Specifically, table B.2 summarizes the tax schemes. Qualitatively, the results are the same as in Experiment 2, except that wealth inequality decreases further due to decreased tax burdens.

	Property Tax Rates (%)	Income Tax Rate (%)
Benchmark	0.13	39.305
Exp 2-1	0.26	39.290
Exp 2-2	(0.13, 0.26)	39.299
Exp 2-3	(0.13, 0.39)	39.293

Table B.2: Alternative Tax Schemes (Experiment 3)

	Homeowner (A)	Landlord (B)	Renter	B / A
Benchmark	60.9345	2.6302	39.0655	0.04317
Exp 3-1	60.9351	2.6164	39.0649	0.04294
Exp 3-2	60.9371	2.6188	39.0629	0.04298
Exp 3-3	60.9374	2.6180	39.0626	0.04296

Table B.3: Change in Housing Tenure (%)

	Percentile					Gini
	60	40	30	20	10	
Benchmark	0.9738	0.8747	0.7748	0.6262	0.4034	0.62592
Exp 3-1	0.9739	0.8747	0.7752	0.6259	0.4029	0.62600
Exp 3-2	0.9739	0.8745	0.7750	0.6259	0.4029	0.62591
Exp 3-3	0.9739	0.8745	0.7748	0.6256	0.4025	0.62572

Table B.4: Change in the Wealth Distribution

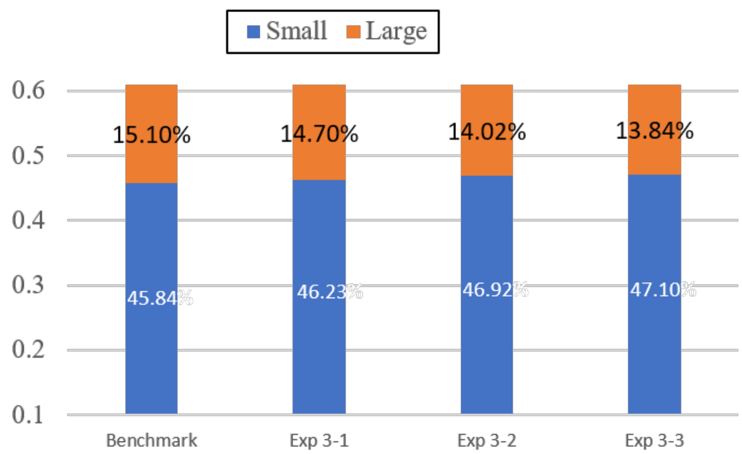


Figure B.1: Change in Housing Distribution (Extension to Experiment 2)

Bibliography

Nobuhiro Kiyotaki, Alexander Michaelides, and Kalin Nikolov. Winners and Losers in Housing Markets. *Journal of Money, Credit and Banking*, 43(2-3):255–296, March 2011. ISSN 1538-4616. doi: 10.1111/j.1538-4616.2011.00374.x.

Kamila Sommer, Paul Sullivan, and Randal Verbrugge. The equilibrium effect of fundamentals on house prices and rents. *Journal of Monetary Economics*, 60(7): 854–870, October 2013. ISSN 03043932. doi: 10.1016/j.jmoneco.2013.04.017.

John Y. Campbell and João F. Cocco. How do house prices affect consumption? Evidence from micro data. *Journal of Monetary Economics*, 54(3):591–621, April 2007. ISSN 03043932. doi: 10.1016/j.jmoneco.2005.10.016.

Greg Kaplan, Kurt Mitman, and Gianluca Violante. Consumption and house prices in the Great Recession: Model meets evidence. *Manuscript, New York University*, 2015.

Fudong Zhang. Inequality and House Prices. 2015.

Mariacristina De Nardi. Wealth inequality and intergenerational links. *The Review of Economic Studies*, 71(3):743–768, 2004.

Mariacristina De Nardi and Fang Yang. Wealth inequality, family background, and estate taxation. *Journal of Monetary Economics*, 77(Supplement C):130–145, February 2016. ISSN 0304-3932. doi: 10.1016/j.jmoneco.2015.10.005.

S. Rao Aiyagari. Uninsured Idiosyncratic Risk and Aggregate Saving. *The Quarterly Journal of Economics*, 109(3):659–684, August 1994. ISSN 0033-5533. doi: 10.2307/2118417.

Mark Huggett. Wealth distribution in life-cycle economies. *Journal of Monetary Economics*, 38(3):469–494, December 1996. ISSN 0304-3932. doi: 10.1016/S0304-3932(96)01291-3.

Per Krusell and Jr. Smith, Anthony A. Income and Wealth Heterogeneity in the Macroeconomy. *Journal of Political Economy*, 106(5):867–896, October 1998. ISSN 0022-3808. doi: 10.1086/250034.

Marco Cagetti. Entrepreneurship, Frictions, and Wealth. *journal of political economy*, page 36, 2006.

Jack Favilukis, Sydney C. Ludvigson, and Stijn Van Nieuwerburgh. The Macroeconomic Effects of Housing Wealth, Housing Finance, and Limited Risk Sharing in General Equilibrium. *Journal of Political Economy*, 125(1):140–223, 2017.

Arthur Acolin, Jesse Bricker, Paul Calem, and Susan Wachter. Borrowing Constraints and Homeownership. *American Economic Review*, 106(5):625–629, May 2016. ISSN 0002-8282. doi: 10.1257/aer.p20161084.

Donald R. Haurin, Patric H. Hendershott, and Susan M. Wachter. Wealth Accumulation and Housing Choices of Young Households: An Exploratory Investigation. *Journal of Housing Research*, 7(1):33–57, 1996. ISSN 1052-7001.

Martin Gervais. Housing taxation and capital accumulation. *Journal of Monetary Economics*, 49(7):1461–1489, October 2002. ISSN 0304-3932. doi: 10.1016/S0304-3932(02)00172-1.

Fang Yang. Consumption over the life cycle: How different is housing? *Review of Economic Dynamics*, 12(3):423–443, July 2009. ISSN 1094-2025. doi: 10.1016/j.red.2008.06.002.

Matthew Chambers, Carlos Garriga, and Don E. Schlagenhauf. Accounting for Changes in the Homeownership Rate*. *International Economic Review*, 50(3):677–726, August 2009a. ISSN 1468-2354. doi: 10.1111/j.1468-2354.2009.00544.x.

G. D. Hansen. The Cyclical and Secular Behaviour of the Labour Input: Comparing Efficiency Units and Hours Worked. *Journal of Applied Econometrics*, 8(1):71–80, 1993. ISSN 0883-7252.

Antonia Díaz and María José Luengo-Prado. On the user cost and homeownership. *Review of Economic Dynamics*, 11(3):584–613, July 2008. ISSN 1094-2025. doi: 10.1016/j.red.2007.12.002.

Antonia Díaz and Marıa J. Luengo-Prado. The user cost, home ownership and housing prices: Theory and evidence from the US. 2011.

Matthew S. Chambers, Carlos Garriga, and Don Schlagenhauf. The loan structure and housing tenure decisions in an equilibrium model of mortgage choice. *Review of Economic Dynamics*, 12(3):444–468, July 2009b. ISSN 10942025. doi: 10.1016/j.red.2009.01.003.

Matthew Chambers, Carlos Garriga, and Don E. Schlagenhauf. Housing policy and the progressivity of income taxation. *Journal of Monetary Economics*, 56(8):1116–1134, November 2009c. ISSN 03043932. doi: 10.1016/j.jmoneco.2009.10.007.

Kamila Sommer and Paul Sullivan. Implications of US Tax Policy for House Prices, Rents, and Homeownership. *American Economic Review*, 108(2):241–274, February 2018. ISSN 0002-8282. doi: 10.1257/aer.20141751.

Antonia Díaz and María José Luengo-Prado. The Wealth Distribution with Durable Goods*. *International Economic Review*, 51(1):143–170, February 2010. ISSN 1468-2354. doi: 10.1111/j.1468-2354.2009.00574.x.

Joseph W. Gruber and Robert F. Martin. Precautionary Savings and the Wealth Distribution with Illiquid Durables. SSRN Scholarly Paper ID 478042, Social Science Research Network, Rochester, NY, November 2003.

Thomas F. Cooley and Edward C. Prescott. Economic growth and business cycles. *Frontiers of business cycle research*, 1, 1995.

Paul Gomme and Peter Rupert. Theory, measurement and calibration of macroeconomic models. *Journal of Monetary Economics*, 54(2):460–497, 2007.

Emmanuel Saez and Gabriel Zucman. Wealth Inequality in the United States since 1913: Evidence from Capitalized Income Tax Data. *The Quarterly Journal of Economics*, 131(2):519–578, May 2016. ISSN 0033-5533, 1531-4650. doi: 10.1093/qje/qjw004.

Morris A. Davis and Jonathan Heathcote. The price and quantity of residential land in the United States. *Journal of Monetary Economics*, 54(8):2595–2620, November 2007. ISSN 0304-3932. doi: 10.1016/j.jmoneco.2007.06.023.

William G. Gale and John Karl Scholz. Intergenerational Transfers and the Accumulation of Wealth. *The Journal of Economic Perspectives*, 8(4):145–160, 1994. ISSN 0895-3309.

Michael D. Hurd and James P. Smith. Anticipated and actual bequests. In *Themes in the Economics of Aging*, pages 357–392. University of Chicago Press, 2001.

William G. Gale and Joel B. Slemrod. Rethinking the estate and gift tax: Overview. Technical report, National Bureau of Economic Research, 2001.

Thesia I. Garner and Randal Verbrugge. Reconciling user costs and rental equivalence: Evidence from the US consumer expenditure survey. *Journal of Housing Economics*, 18(3):172–192, September 2009. ISSN 10511377. doi: 10.1016/j.jhe.2009.07.001.

Morris A. Davis and François Ortalo-Magné. Household expenditures, wages, rents. *Review of Economic Dynamics*, 14(2):248–261, April 2011. ISSN 10942025. doi: 10.1016/j.red.2009.12.003.

Jesús Fernández-Villaverde and Dirk Krueger. Consumption and saving over the life cycle: How important are consumer durables? *Macroeconomic Dynamics*, 15(05):725–770, November 2011. ISSN 1365-1005, 1469-8056. doi: 10.1017/S1365100510000180.

Laurie Goodman. Sixty Years of Private Mortgage Insurance in the United States. *Urban Institute*, page 52, August 2017.

Heinry A Aron. Income Taxes and Housing. *The American Economic Review*, page 19, 1970.

Harvey S. Rosen. Owner occupied housing and the federal income tax: Estimates and simulations. *Journal of Urban Economics*, 6(2):247–266, April 1979. ISSN 0094-1190. doi: 10.1016/0094-1190(79)90008-1.

Edward L. Glaeser. Housing policy in the wake of the crash. *Daedalus*, 139(4): 95–106, October 2010. ISSN 0011-5266. doi: 10.1162/DAED_a_00046.

OECD. Housing and the economy: Policies for renovation. *Economic Policy Reforms 2011: Going for Growth.*, 2011.

Richard Ronald and Mee-Youn Jin. Homeownership in South Korea: Examining Sector Underdevelopment. *Urban Studies*, 47(11):2367–2388, October 2010. ISSN 0042-0980, 1360-063X. doi: 10.1177/0042098009357967.

Ho Soon Shin and Hyun Chang Yi. The Korean Housing Market: Its Characteristics and Policy Responses. In Rob Nijskens, Melanie Lohuis, Paul Hilbers, and Willem Heeringa, editors, *Hot Property: The Housing Market in Major Cities*, pages 181–194. Springer International Publishing, Cham, 2019. ISBN 978-3-030-11674-3. doi: 10.1007/978-3-030-11674-3_16.

Sang-Wook (Stanley) Cho. Accounting for life-cycle wealth accumulation: The role of housing institution. *Macroeconomic Dynamics*, 16(4):493–517, September 2012. ISSN 1365-1005, 1469-8056. doi: 10.1017/S1365100510000659.

Sang-Wook (Stanley) Cho. Household wealth accumulation and portfolio choices in Korea. *Journal of Housing Economics*, 2010. doi: 10.1016/j.jhe.2009.10.002.

George Tauchen and Robert Hussey. Quadrature-Based Methods for Obtaining Approximate Solutions to Nonlinear Asset Pricing Models. *Econometrica*, 59(2): 371–396, 1991. ISSN 0012-9682. doi: 10.2307/2938261.

A. Mnasri. Renting vs buying a home: A matter of wealth accumulation or of geographic stability? *Journal of Economic Dynamics and Control*, 60:42–72, November 2015. ISSN 0165-1889. doi: 10.1016/j.jedc.2015.08.008.

Hyeongjun Kim, Hoon Cho, and Doojin Ryu. Characteristics of Mortgage Terminations: An Analysis of a Loan-Level Dataset. *The Journal of Real Estate Finance and Economics*, 57(4):647–676, November 2018. ISSN 0895-5638, 1573-045X. doi: 10.1007/s11146-017-9620-5.

Ana Castañeda, Javier Diaz-Gimenez, and Jose-Victor Rios-Rull. Accounting for the US earnings and wealth inequality. *Journal of political economy*, 111(4):818–857, 2003.