Negative Gearing and Welfare: A Quantitative Study for the Australian Housing Market *

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Abstract

This paper explores the implications of negative gearing tax associated with housing investment by conducting a quantitative study of the Australian housing market. We build a general equilibrium overlapping generations model with incomplete markets and heterogeneous agents which features income taxes and negative gearing tax that are consistent with the Australian practice. Comparing across the stationary equilibria with and without negative gearing tax, we find that removing negative gearing would result in lower house prices, higher rents and homeownership rate. Improvements in homeownership rate are observed predominantly among young and middle-aged households who are relatively poor. The welfare analysis suggests that eliminating negative gearing would lead to an overall welfare gain of 1.5 percent for the Australian economy in which 76 percent of households become better off. However, the welfare effects are heterogeneous across different households. Renters and owner-occupiers are winners, but landlords, especially young with high earning landlords, lose.

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1 Introduction

Many governments promote investment in housing markets by providing tax concessions to landlords. In Australia, negative gearing is the process by which housing investors can deduct housing investment losses from their gross income.[1] The annual government expenditure on negative gearing is estimated to be $2 billion, which constitutes 5 percent of the budget deficit for the year 2016 (Australian Treasury and Grattan Institute, 2016). Potential reforms to negative gearing are hotly debated.[2] Supporters of negative gearing argue that the policy stabilizes the rental market as it stimulates the supply of rental properties. The policy therefore helps renters who are mostly low income earners. However, opponents argue that negative gearing puts additional upward pressure on housing prices, making houses less affordable.

This paper aims to quantitatively examine the welfare implications of negative gearing. To do so, we develop a general equilibrium overlapping generations model with heterogeneous agents that features endogenous house prices and rents, as well as the demand and supply decisions for rental properties. The model economy is populated by overlapping generations of finitely-lived households who differ along age and earnings dynamics, and such heterogeneity allows us to identify the group of households that benefits or loses from the elimination of negative gearing. Households derive utility from a numeraire non-durable consumption good and housing services, and in each period, they choose to become renters or homeowners. Buying and selling a home are subject to a lumpy transaction cost. A decision to purchase a house provides access to collateralized borrowing which requires a minimum downpayment. Homeowners can lease out houses in the rental market and claim tax deductions for the loss incurred from their housing investment. House prices are subject to an idiosyncratic shock that yields potential capital gains or losses for different house-

[1]Negative gearing is not unique to Australia. Several OECD countries including New Zealand, Canada and Japan provide a full negative gearing concession to offset taxes from other income sources. Other countries such as the U.S., Germany, France, Switzerland and Sweden allow partial offsetting against the loss from housing investment.

[2]For instance, the current opposition (Australian Labor Party) proposes to limit negative gearing to newly constructed housing from the 1st of July 2017.

holds, and this generates sizable negatively geared landlords in the stationary equilibrium. The government collects taxes, which are progressive, and redistributes them in a lump-sum fashion. The presence of a progressive tax system and lump-sum transfers has important implications for households' decision to become landlords and redistributive channels in our counterfactual policy experiment as a reform that eliminates negative gearing would impact differently for households in the different income brackets. A housing construction sector responds to the changes in prices and adjusts the supply of new housing stocks.

The model is calibrated to match relevant moments of the Australian housing market. We estimate an idiosyncratic shock to household earnings, which provides a key source of heterogeneity in our model, using data from a longitudinal household survey.[3] A tax function is calibrated to mimic the current tax system of the Australian economy. The model can match homeownership and landlord rates over the life-cycle and across the earnings distribution in the data. The model also generates the proportion of negatively geared landlords, house value-to-income, loan-to-value and loan-to-income ratios that are similar to the data counterparts.

Our model shows that eliminating negative gearing would reduce housing investments and house prices, and increase the average homeownership rate. Comparing across the stationary equilibria, removing negative gearing increases the average homeownership rate by 5.5 percent. In the counterfactual economy, the effective cost of housing investment is higher, depressing the aggregate demand for housing stocks and therefore housing prices. Lower house prices improve housing affordability as both the downpayment requirement for mortgages and the transaction costs associated with housing purchase decrease. This particularly benefits those low-income credit constrained households who were at the margin of being homeowners, and the improvements in the homeownership rate are prominent among these households. As the supply of rental properties falls, rents increase but only marginally because its demand also falls. The small increase in rents also makes homeownership relatively less expensive and this leads renters with high earnings to become

[3]We use the Household, Income, and Labour Dynamics in Australia (HILDA) survey for the estimation of earnings process. We provide more details about this in a technical appendix.

homeowners. The policy change has significant impacts on the composition of landlords. Landlords who rely on borrowings to finance their investment, and hence benefit the most from negative gearing, are driven out of the market for investment properties. Most of these landlords are young but rich enough to afford the downpayment requirement for their investment. It also contracts the amount of mortgage holdings for landlords, and the decrease in the size of mortgage holdings is larger for households in upper income percentiles.

The majority of households experience welfare gains when negative gearing is removed. Our welfare analysis suggests that around 76 percent of households prefer to live in an economy without negative gearing. The overall welfare for the economy also improves by 1.5 percent. The general equilibrium effects of the policy change, a decrease in house prices and in particular an increase in transfer payments, make these households better off in the counterfactual economy.[4] The welfare implications differ along dimensions of age, income and housing tenure in which the increase in welfare is regressive across both age and income. Young households who are relatively poor experience higher welfare gains from the reform as the fall in house prices makes it easier to purchase a house for owner-occupied purposes. Poorer renters who would never afford houses even after the reform benefit due to the increased transfer payments. Most young owner-occupiers also benefit from the lower house prices as they can move up a housing ladder more easily. However, landlords especially young with higher earnings who also bear high mortgages are worse off as the policy change reduces their disposable income. The welfare losses for these landlords are larger than any other groups in the economy due to the progressive tax system.

Our paper belongs to a large literature of quantitative studies of the housing market: Jeske, Krueger, and Mitman (2013), Chatterjee and Eyigungor (2015), Corbae and Quintin (2015), and Kaplan, Mitman, and Violante (2017). It is closely related to Gervais (2002), Chambers, Garriga, and Schlagenhauf (2009b), Sommer and Sullivan (2016) and Floetotto, Kirker, and Stroebel (2016) who study the implications of tax policies in the housing markets using quantitative macroeconomic models. Unlike Gervais (2002) and Chambers, Garriga,

[4] In Appendix, we simulate a counterfactual economy that does not allow for redistribution, and show that the welfare gain is largely driven by the increase in lump-sum transfers.

and Schlagenhauf (2009b), our model allows for endogenous house prices, rents, and buy vs. rent decisions. Relative to Sommer and Sullivan (2016) and Floetotto, Kirker, and Stroebel (2016) who focus on the mortgage interest deductibility in the U.S. housing markets, our paper examines the effects of negative gearing which provides tax benefits only to landlords. None of the previous papers discuss the implications of negative gearing tax concessions although it is a common practice in some OECD countries. Our model is different to those in Sommer and Sullivan (2016) and Floetotto, Kirker, and Stroebel (2016) by introducing an idiosyncratic house price shock that generates ex-post capital gains or losses for homeowners. In the absence of house price appreciation, forward-looking landlords are not negatively geared in the stationary equilibrium. Models in Sommer and Sullivan (2016) and Floetotto, Kirker, and Stroebel (2016) may not be suitable if they consider a policy alternative such as restricting mortgage interest deductions to housing investment.[5]

Laidler (1969), Rosen (1985) Poterba (1984, 1992), and Berkovec and Fullerton (1992) also study the impacts of housing tax policies. We contribute to this literature by providing a model that is rich enough for the analysis of welfare and distributional consequences of government policy. Some of earlier papers rely on a dynamic setting, e.g. Poterba (1984, 1992) and Berkovec and Fullerton (1992), but ignore household heterogeneity and the role of a rental market. Considering household heterogeneity and the interaction with the rental market is important when we are interested in the general equilibrium effects on both housing prices and rents, as well as the welfare effects across the different class of households.

The rest of this paper is organized as follows: Section 2 describes the background of negative gearing in the Australian housing market. Sections 3 discusses the model. Section 4 describes the calibration strategy and some important quantitative properties of the baseline model. Section 5 discusses the result of this paper, the price and quantity effects of negative gearing and its impact on aggregate and distributional welfare. Section 6 concludes.

[5] Currently, the U.S. government allows both owner-occupiers and landlords to deduct mortgage interest expenses from their income.

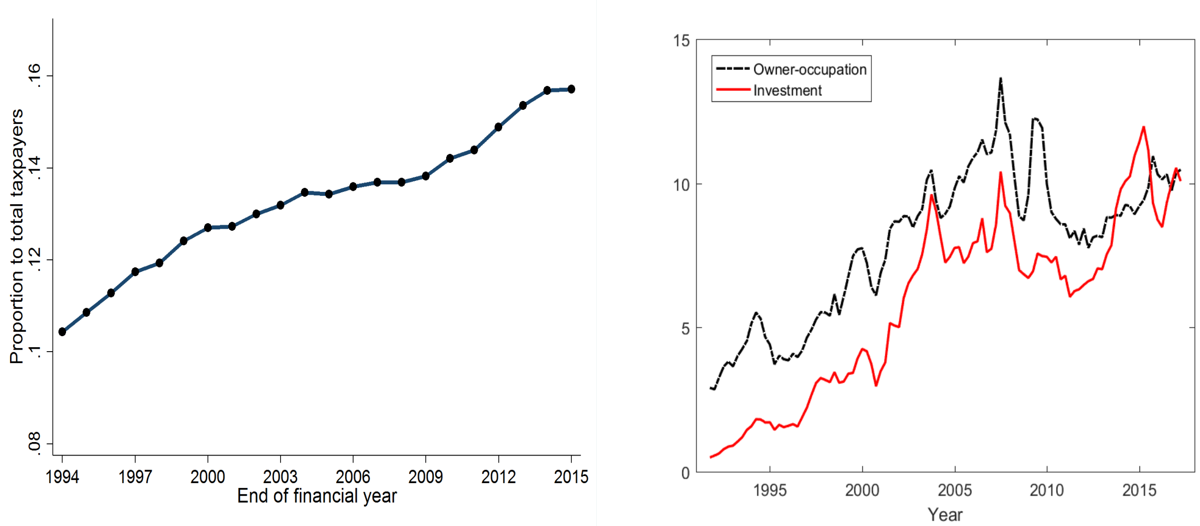

Figure 1: Taxable landlords (left) and Real housing loan approvals in billions (right)

Source: Taxation Statistics, Table 1 Individual, Australian Taxation Office (ATO); Cat. No. 5609.0 Housing Finance Commitment, Australian Bureau of Statistics (ABS). Note: Housing loan approval series are deflated by the price index of housing, sourced from Cat. No. 6401.0 Consumer Price Index, ABS.

2 Background

Housing has been increasingly a popular source of investment in Australia.[6] The left panel in Figure 1 shows that the proportion of landlords has risen by around 50 percent over the last two decades. The right panel in Figure 1 shows that the real housing loan approvals have also increased dramatically during the same period. In particular, the loan approvals for investment purposes increased more sharply than that for owner-occupied purposes, surpassing it by around \$0.5 billion in the early 2010s.

The tax treatment of negative gearing allows landlords to fully deduct the interest on investment loans and on-going expenses including depreciation from their gross income.[7] Figure 2 documents the proportion negatively geared landlords and the aggregate net rental income across the period from 1994 to 2015. The left panel in Figure 2 shows that the proportion of negatively geared landlords has increased from 50 percent in 1994 to around 60

[6] Another favorable tax treatment to landlords in Australia is 50 percent discount on capital gains tax which was introduced in 1999.

[7] Other on-going expenses on investment properties may include body corporate fees, insurance, property agent fees, and maintenance costs.

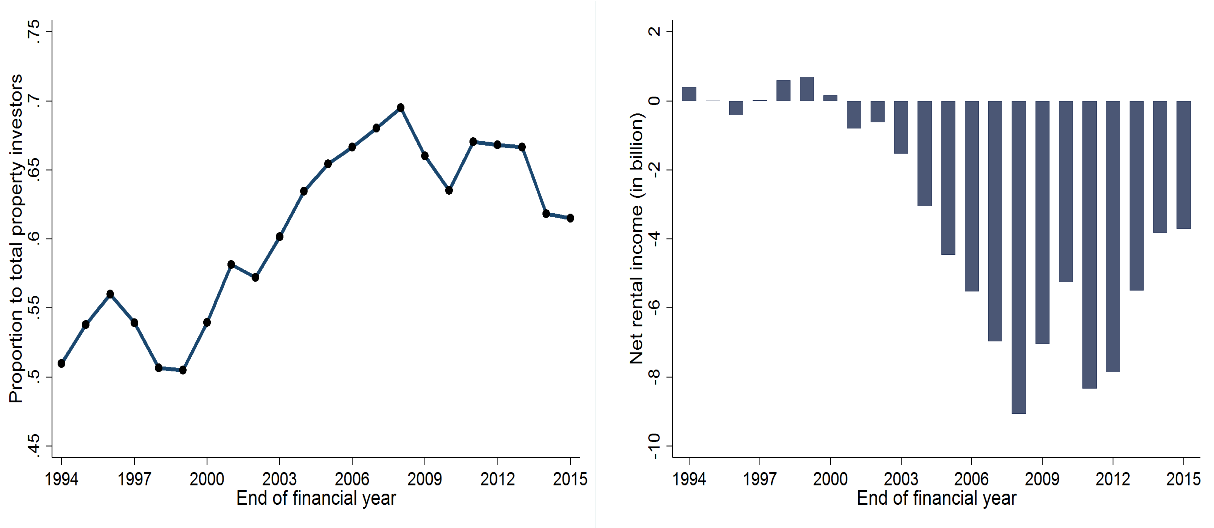

Figure 2: Negatively geared landlords (left) and Net rental income (right)

Source: Taxation Statistics, Table 1 Individual, ATO

percent in 2015. The right panel in Figure 2 shows that the aggregate net rental income became large negative from the early 2000s onwards. Evidence shown in Figures 1 and 2 suggest that Australian households increasingly participate in the residential property investment and take advantage of negative gearing, reducing tax obligations with the flow loss incurred from their housing investment.

Figure 3 compares the share of households with home loans for investment by age (left panel) and income percentile (right panel) for the years 2002 and 2014. There has been a significant increase in the share, particularly among young to middle-aged households. The largest increase was occurred in the age group $25 - 35$, increased by 85 percent from 7 percent to 13 percent. From the right panel, we find that the share of households with investment housing loans has increased mainly among those in upper income percentiles. These evidence are in line with the arguments by opponents of negative gearing that the policy essentially benefits the rich households who borrow and speculate in the property market. The fact that the distribution of housing investment loans is different across age and income also motivates our use of a heterogeneous agents incomplete markets model to study the implications of negative gearing.

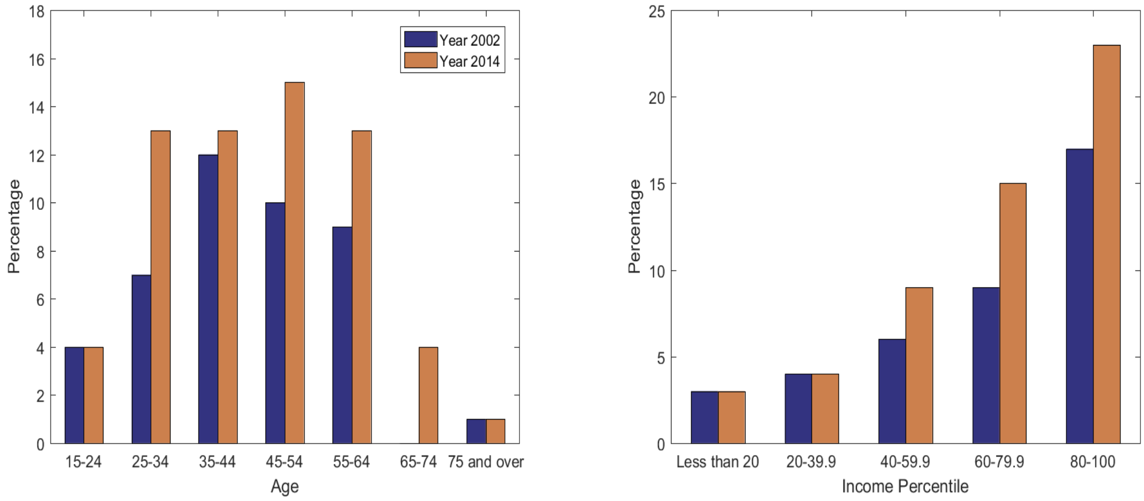

Figure 3: Households with investment housing loan: By age (left) and income (right)

Source: Statistical Table E7 – Household Debt Distribution, Reserve Bank of Australia

3 Model

To analyze the effects of negative gearing on the Australian housing market, we develop an overlapping generations general equilibrium model with heterogeneous agents. The economy is populated by overlapping generations of households who are subject to uninsurable idiosyncratic income shocks. Households derive utility from a numeraire non-durable consumption good and housing services, which can be obtained via renting or owning. Homeowners can purchase additional units of housing stock and lease to other households. The decision to become a landlord is affected by the government taxation policy. Purchasing and selling housing stocks incur non-convex transaction costs and homeowners are required to pay maintenance costs to prevent housing stocks from depreciation. In every period, the equilibrium price and rent are determined by the market clearing conditions for the housing and rental markets. A competitive construction sector adjusts the supply of new housing stocks in response to changes in prices.

3.1 Households

Demographics. The economy is populated by a continuum of finitely-lived households who live and work for $a = 1, 2, ..., A$ periods. Throughout the life-cycle, households face an age-dependent survival rate of κ_a, and they all die with certainty after period A.

Preferences. Households derive utility from consumption of non-durables c and housing services $\tilde{h}$. The expected lifetime utility of the household is given by:

$$\mathbb{E}_0 \left[\sum_{a=1}^{A} \beta^{a-1} \kappa_a u_a(c_a, \tilde{h}_a) \right] \tag{1}$$

with $\beta > 0$. The periodic utility of household is given by:

$$u(c, \tilde{h}) = \frac{\left[c^{\alpha} \left(\lambda \tilde{h} \right)^{1-\alpha} \right]^{1-\sigma}}{1 - \sigma} \tag{2}$$

where α denotes preference for non-durables and σ is a risk aversion coefficient. Since there may be additional utility from living in an owned home, we assume that homeowners receive premium of λ, with $\lambda > 1$ for homeowners and $\lambda = 1$ for renters.

A household who dies unexpectedly has all his assets, taken by the government and liquidated if needed. After settling outstanding debt, the remaining assets are distributed equally to every surviving household in the economy.

Endowment. A household i with age a supplies a unit of labor inelastically and receives an income of $y_{i,a}$. The process of earnings is expressed as:

$$\log y_{i,a} = \eta_a + z_{i,a} \tag{3}$$

where η_a is a deterministic component of income that depends on households' age and $z_{i,a}$

is a persistent idiosyncratic component, which follows an AR(1) process as below:

$$z_{i,a} = \rho z_{i,a-1} + u_{i,a} \qquad u_{i,a} \sim N(0, \sigma_u^2) \tag{4}$$

The idiosyncratic income shock is the main source of household heterogeneity in our model. It generates a dispersion of households within and across age groups. This allows us to compare the extensive margin of housing tenure and investment decision among households. The idiosyncratic income shock is also important for generating the life-cycle savings patterns observed in the data as it creates a precautionary savings motive.

Housing arrangements. The housing asset is denoted by h, available in K discrete sizes. Households may not choose to purchase a house $(h = 0)$ in which case they obtain housing services via renting $(h^{\text{rent}} > 0)$. Homeowners obtain housing services from a house they purchased $(h^{\text{own}} > 0)$. The amount of housing services consumed is given by:

$$\tilde{h} = \begin{cases} h^{\text{rent}} & \text{if renter} \\ h^{\text{own}} & \text{if owner-occupier} \end{cases}$$

Renters are allowed to live in units smaller than the minimum house size available to owner-occupiers.[8] They can also rent any of larger sizes. Households can become landlords by purchasing more housing units than they consume $(h - \tilde{h} > 0)$ but cannot derive utility from it. For a given housing size, homeowners can freely switch their dwelling from owner-occupied houses to investment properties (or vice versa). By assumption, we do not allow homeowners to consume more housing services than what they purchased in which case they would become net renters. We also prevent renters from purchasing investment properties, i.e. no renter-landlords.[9]

Maintenance and transaction costs. Homeowners incur maintenance expenses, which

[8] One can think of these units as studio apartments or shared rooms.

[9] In the data, approximately 3 percent of the population are renters who are also landlords.

is linear in the housing value, in order to offset physical depreciation of housing stocks. We use δ to denote any costs associated with maintenance of housing stocks. In addition, landlords incur an additional fixed cost ζ which captures a cost related to finding tenants and managing rental property.

Houses are costly to buy and sell. Households face transaction costs of ϕ^b percent of the house value when buying a house and ϕ^s percent when selling a house. Thus, the total transaction costs for buying and selling a house are $\phi^b ph$ and $\phi^s ph_{-1}$. The presence of transaction costs generates sizable inaction regions with respect to the household decision to buy or sell. We use $TC(h_{-1}, h)$ to describe transaction costs associated with owner-occupied and investment housing. They are expressed as:

$$TC(h_{-1}, h) = \begin{cases} 0 & \text{if} \quad h_{-1} = h \\ \phi^b ph + \phi^s ph_{-1} & \text{if} \quad h_{-1} \neq h \end{cases}$$

These transaction costs are a dead-weight loss for the economy.[10]

Borrowing and saving. Households have access to a risk-free asset, s' that pays interest r. In any period, a household can save by purchasing this risk-free asset in which case s' will be positive. He can also borrow in which case s' becomes negative. The market incompleteness implies that households can only borrow using housing stocks as collateral and the borrowing requires the downpayment of θph. The constraint on s' is expressed as:

$$s' \geq -(1-\theta)ph \tag{5}$$

If the household is a borrower, he needs to pay mortgage premium of m. We also assume that the model hinges on a small open economy so that the interest rate r is exogenous.

Housing price risk. To introduce ex-post capital gain or loss from housing investment, we

[10]The stamp duties are collected by the State government in Australia.

introduce an idiosyncratic housing price shock, following Chambers, Garriga, and Schlagenhauf (2009a,b). The decision to sell housing assets results in households being subject to an idiosyncratic house price shock, $\omega \in \Omega$, that influences the final selling price of a house. Although the selling price may be higher (lower) when a positive (negative) shock is realized, the stationary equilibrium is preserved as the ex-ante expected capital gain is zero, i.e. $\mathbb{E}(\omega p) = p$. Households have no information of about this i.i.d. shock until the house is sold, but they know the unconditional probability of the shock which is given by π_ω. To avoid the complication of households buying housing assets at different prices, we assume that the competitive construction firm (to be described later) buys from all selling households (at different prices) and sells to all purchasing households at a constant price p.[11]

Taxation and transfers. Households pay tax on labor income, capital income and the net rental income (NRI), which is defined as:

$$NRI \equiv (p^r - p\delta)(h - \tilde{h})\mathbb{1}_{\{h>\tilde{h}\}} + (r + m)s\left(\frac{h - \tilde{h}}{h}\right)\mathbb{1}_{\{h>\tilde{h}\wedge s<0\}} - \zeta\mathbb{1}_{\{h>\tilde{h}\}} \tag{6}$$

The first term on the RHS is rental receipts after paying maintenance costs. The last term is the periodic fixed cost associated with being a landlord, where $\mathbb{1}_{\{h>\tilde{h}\}}$ is an indicator for landlords. In the second term, $(r + m)s$ is the total interest payments on mortgages, $\frac{h-\tilde{h}}{h}$ is the proportion of investment to total housing stocks owned by a landlord, and $\mathbb{1}_{\{h>\tilde{h}\wedge s<0\}}$ is an indicator for landlords with mortgages. The second term therefore represents the mortgage interest payments for investment properties. Here, we make a simplifying assumption that mortgages for investment properties and owner-occupied properties charge the same interest rate and they are amortized at the same rate.[12]

[11] The construction firm can sell houses at a constant price since on average it will make zero capital gains from the sales.

[12] In real-life, some landlords would payoff mortgages for owner-occupied houses first and leave behind those for investment housing to maximize tax deductions. Distinguishing mortgages between owner-occupied and investment housing would require another state variable which puts additional computational burden in solving the model.

Accordingly, the total taxable income is expressed as:

$$Y = y_a + rs\mathbb{1}_{\{s>0\}} + NRI \tag{7}$$

which suggests that, if a housing investor is making a loss from his housing investment, i.e. $NRI < 0$, he can reduce the amount of taxable income. The total tax payment is represented by $T(Y)$, which we describe the exact details in Section 3.2. In the baseline economy, the taxable income is expressed according to (7). In Section 5, we run a counter-factual policy experiment by setting the taxable income as below:

$$Y = y_a + rs\mathbb{1}_{\{s>0\}} + NRI\mathbb{1}_{\{NRI>0\}} \tag{8}$$

This suggests that landlords would have a higher taxable income when they make a positive profit from housing investment but cannot reduce the income when a loss is realized.

Households receive lump-sum transfers, F, which the government finances through taxation and liquidating the assets of households who unexpectedly die. We can now express the budget constraint for a household in an arbitrary policy regime as follow:

$$\begin{aligned} c + s' + ph + TC(h_{-1}, h) + T(Y) + \zeta\mathbb{1}_{\{h>\tilde{h}\}} = y_a + p\omega(1-\delta)h_{-1} + p^r(h - \tilde{h}) \\ + (1 + r + m\mathbb{1}_{\{s<0\}})s + F \end{aligned} \tag{9}$$

3.1.1 Household Dynamic Programming Problem

In each period, given price, rent and transfer payment (p, p^r, F), households choose whether (i) to rent, or (ii) to own a house. If they decide to own, they also decide upon investment in housing. Household's current state comprises of four individual variables: housing assets h_{-1}, savings s, the current realization of idiosyncratic income shock z, and household's age a. For notational convenience, we group these state variables into $x \equiv (a, s, h_{-1}, z)$. The value functions are written as:

$$V(x) = \max\{V^{\text{rent}}(x), V^{\text{own}}(x)\} \tag{10}$$

Renter's problem. Renters do not purchase any housing assets ($h = 0$). Instead, they choose housing services by entering the rental market. Those who decide to be renters solve:

$$V^{\text{rent}}(x) = \max_{c_\omega, \tilde{h}_\omega, s'_\omega} \sum_{\omega \in \Omega} \left\{ \pi_\omega \left[u(c_\omega \tilde{h}_\omega) + \beta \kappa_a \mathbb{E}_{z'|z} V(x') \right] \right\} \tag{11}$$

subject to

$$c_\omega + s'_\omega + p^r \tilde{h}_\omega + TC(h_{-1}, 0) + T(Y) = y_a + p\omega(1-\delta)h_{-1} + (1 + r + m\mathbb{1}_{\{s<0\}})s + F$$
$$\tilde{h}_\omega = h_\omega^{\text{rent}}$$
$$s'_\omega \geq 0$$
$$Y = y_a + rs\mathbb{1}_{\{s>0\}}$$

Homeowner's problem. Homeowners consume housing services by purchasing housing stocks. They may choose to consume all of their housing assets ($h = \tilde{h} > 0$) in which they will be owner-occupiers. They also have an option to buy more housing stocks than they consume ($h > \tilde{h} > 0$) in which case they become landlords. Homeowners solve:

$$V^{\text{own}}(x) = \max_{c_\omega \tilde{h}_\omega, s'_\omega, h_\omega} \sum_{\omega \in \Omega} \left\{ \pi_\omega \left[u(c_\omega, \tilde{h}_\omega) + \beta \kappa_a \mathbb{E}_{z'|z} V(x') \right] \right\} \tag{12}$$

subject to

$$
\begin{aligned}
c_\omega + s'_\omega + ph_\omega + TC(h_{-1}, h_\omega) + T(Y) + \zeta\mathbb{1}_{\{h_\omega > \tilde{h}_\omega\}} &= y_a + p\omega(1-\delta)h_{-1} + p^r(h_\omega - \tilde{h}_\omega) \\
&\quad + (1 + r + m\mathbb{1}_{\{s<0\}})s + F \\
\tilde{h}_\omega &= h_\omega^{\text{own}} \\
s'_\omega &\geq -(1-\theta)ph_\omega \\
Y &= y_a + rs\mathbb{1}_{\{s>0\}} + NRI
\end{aligned}
$$

where NRI is given by (6). Notice that all choice variables are now indexed by ω since households' choice depends on the realization of the i.i.d. house price shock upon the sales of housing assets.

3.2 Government

This section provides a parsimonious representation of the Australian tax system in which households' taxable income is taxed at different marginal rates. The total amount of taxation imposed on households is determined by

$$
T(Y) = \begin{cases}
0 & \text{if } Y \leq \bar{Y}_1 \\
\tau_1(Y - \bar{Y}_1) & \text{if } \bar{Y}_1 < Y \leq \bar{Y}_2 \\
T_1 + \tau_2(Y - \bar{Y}_2) & \text{if } \bar{Y}_2 < Y \leq \bar{Y}_3 \\
\vdots & \\
T_{Q-2} + \tau_{Q-1}(Y - \bar{Y}_Q) & \text{if } \bar{Y}_{Q-1} < Y \leq \bar{Y}_Q
\end{cases}
$$

where $\bar{Y}_q$s are income thresholds, τ_q is the marginal tax rates, T_q is the tax payment threshold. It is assumed that $T_q = T_{q-1} + \tau_q(\bar{Y}_{q+1} - \bar{Y}_q)$.

Apart from taxation, the government finances its spending by selling the wealth of deceased households. Each period, the government sells housing stocks owned by those who die unexpectedly and pays off any outstanding debt. We use the letter R to denote these residual wealth collected by the government. The government spends all of its revenue by distributing lump-sum transfers equally to living households, denoted by F. A household who dies unexpectedly therefore leaves accidental bequests. The presence of lump-sum transfers is important for redistributive channels as a reform that increases government's taxation revenue may benefit young and poor households in the counterfactual economy as lump-sum transfer would increase. The government runs a balanced budget in every period.

3.3 Construction Sector

There is a competitive construction firm that governs the aggregate housing supply of the economy. The firm buys existing dwellings from households who choose to sell their housing assets, develops new dwellings using a production technology, and sells existing and new dwellings at price p to households who choose to purchase housing assets. Because there is no capital gain on average, the competitive construction firm does not earn profits from buying and selling existing dwellings. Following Floetotto, Kirker, and Stroebel (2016), we assume that the production technology of this construction firm, $H^{\text{new}} = \psi_1 L^{\psi_2}$ where L is the amount of land available for development. All of these land were previously occupied but the depreciation process frees up some for development. The firm purchases the land at a constant price which is normalized to 1, and sells the newly produced housing stock in the market at price p. The parameter ψ_2 is a scale parameter that is less than 1. The construction firm therefore solves the following static problem:

$$\max_{L} \left\{ p\psi_1 L^{\psi_2} - L \right\} \tag{13}$$

which results in the following transition equation for the aggregate housing stock:

$$H = H_{-1}(1-\delta) + H^{\text{new}} = H_{-1}(1-\delta) + \psi_1 \left(\frac{1}{\psi_1 \psi_2 p} \right)^{\frac{\psi_2}{\psi_2 - 1}} \tag{14}$$

Note that the aggregate housing supply elasticity is given by $\varepsilon = \psi_2/(1-\psi_2)$.

3.4 Stationary Equilibrium

The individual state variables are holdings for financial assets, s, housing stocks, h_{-1}, realization of idiosyncratic earnings shock, z, and age of household, a. Let $x = (s, h_{-1}, z, a)$ denote the state vector of household's decision. Let $s \in S = \mathbb{R}_+$, $h_{-1} \in H = \{0, h(1), ..., h(K)\}$, $z \in Z = \{z_1, ..., z_J\}$, and $a \in A = \{1, ..., A\}$. The individual state space is then given by $X = S \times H \times Z \times A$. A stationary equilibrium consists of value functions $V(x)$, household decision rules $\{c_\omega(x), s'_\omega(x), h_\omega(x), \tilde{h}_\omega(x)\}$, a housing stock $\overline{H}$, lump-sum transfers F, and a stationary distribution on X, μ such that:

1. Household optimize by solving problems (10)-(12) with value functions $\{V^{\text{rent}}(x), V^{\text{own}}(x)\}$ and decision rules $\{c_\omega(x), s'_\omega(x), h_\omega(x), \tilde{h}_\omega(x)\}$.
2. The aggregate housing stock satisfies (14) with $H = H_{-1} = \overline{H}$.
3. The housing and rental markets clear:

$$\int_X h_\omega(x) d\mu = \overline{H} \tag{15}$$

$$\int_X \left(\tilde{h}_\omega(x) - h_\omega(x)\right) d\mu = 0 \tag{16}$$

4. The government budget is balanced

$$\int_X T(Y(x)) d\mu + R = \int_X F d\mu \tag{17}$$

5. The distribution μ is stationary and consistent with household behavior.

4 Calibration

We calibrate parameters in the model in two stages. In the first stage, we calibrate some parameters externally without solving the model. In the second stage, we estimate the remaining parameters by employing a method of moment approach that matches a number of model moment from the baseline steady state to their data counterpart as close as possible. We summarize parameters that externally determined in Table 1 and estimated parameters and respective moments in Table 2.

4.1 Externally Calibrated Parameter Values

Demographics. The model period is set to 5 years. Households enter the model at age 21 and exit at age 90. Thus, the number of age cohorts is 14. The age dependent survival probability, κ_a, is obtained from the ABS Life Table $2007-2009$.

Preferences. The coefficient of risk aversion, σ is set to 2, which is a standard value in macroeconomics. Other parameters in the utility function, α and λ are calibrated internally via estimation.

Endowments. The endowment process is estimated using the age and income data in the Household Labour Income Dynamics Australia (HILDA). To be consistent with the model, we construct the exogenous income by subtracting the investment income (e.g. savings and rental income) from the total gross income. Accordingly, our income measure captures households' gross income that includes pensions and transfers but excludes any investment income. We extract the deterministic component, $\{\eta_a\}_{a=1}^{A=14}$ from a fourth order polynomials in age cohort. This component explains the life-cycle earnings profile that is increasing (decreasing) during the earlier (later) stages of life. The stochastic component of earnings, $z_{i,a}$, is estimated to follow an AR(1) process with persistence of 0.65 and standard deviation for innovations of 0.45.[13] We provide a detailed description of the estimation of the earnings process in Appendix. We discretize a continuous process of earnings into five states using the method of Tauchen and Hussey (1991).[14] The median income in our model is estimated

[13]These are the 5-year values converted using the annual estimates of $\rho = 0.94$ and $\sigma_u^2 = 0.03$. See Appendix for our approach to conversion of the annual value to the 5-year value.

[14]We also apply a weighting function proposed by Floden (2008) that corrects for the critique of Tauchen and Hussey (1991) with a highly persistence process.

to be \$347,800 which is used to normalize other variables in monetary units.

Housing. The transaction costs for buyers come from the weighted average stamp duty for seven capital cities from 2001 to 2014 which is about 3.75 percent of the purchase price, so we set $\phi^b = 0.0375$. The transaction cost for sellers is set $\phi^s = 0.03$ which corresponds to the average real-estate agent fee of 3 percent of the selling price. The maintenance cost is set to offset depreciation. In the SIH 2013-14, we find that homeowners pay maintenance expenses around 2.2 percent of the housing value. This is similar to those reported in the U.S. studies.[15]. Given that, we set $\delta = 0.02$ per year. This translates to the model value of 0.104. The downpayment requirement, θ, is set at 0.2, consistent with the practice in Australia and other advanced economies. The minimum size for owner-occupied housing, $h(1)$ is set to be 80 percent of the model's median income.

Interest rates. The interest paid on the risk-free asset is calibrated from the average yield of the 5-year maturity Commonwealth government bond across January 2001 to December 2015, deflated by annual CPI inflation. This gives us the real interest rate of 1.66 percent per annum, equivalent to the model value of 9.2 percent. The annual mortgage premium is calculated by subtracting the risk-free rate from the real variable lending rates for owner-occupied housing across the same period. The annual average is 2.26 percent which translates to the model value of 11.8 percent. These rates are all obtained from the Reserve Bank of Australia.

Taxation. The income tax function captures the progressivity of the Australian tax system. The parameters to be calibrated are income thresholds for each tax bracket $\bar{Y}_q$, the marginal tax rates τ_q, and the tax payment thresholds for each bracket, T_q. These are obtained from the Australian Taxation Office using the income tax system for the 2012-13 financial year. The function is given by:

[15] For example, Floetotto, Kirker, and Stroebel (2016) reports $\delta = 0.02$ and Sommer and Sullivan (2016) set $\delta = 0.015$.

$$T(Y) = \begin{cases} 0 & \text{if } Y \leq 0.2612 \\ 0.19(Y - 0.2612) & \text{if } 0.2612 < Y \leq 0.5310 \\ 0.0513 + 0.325(Y - 0.5310) & \text{if } 0.5310 < Y \leq 1.1481 \\ 0.2518 + 0.37(Y - 1.1481) & \text{if } 1.1481 < Y \leq 2.5832 \\ 0.7828 + 0.45(Y - 2.5832) & \text{if } 2.5832 < Y \end{cases}$$

House price shock. We take a similar approach to Chambers, Garriga, and Schlagenhauf (2009a,b) in quantifying the idiosyncratic house price shock. The SIH contains information about the purchase price of dwelling and its estimated sale price which homeowners believe to be the current market value. We define capital gains as the difference between these two variables, and convert them into annual values. The shock is then defined as a deviation from the mean. We estimate the distribution of the capital gains shock and discretize it into three equal partitions. The house price shock is given by the median value of each partition, $[0.545 \;\; 1.201 \;\; 1.805]$, which are equivalent to the annual return of $[-0.11 \;\; 0.037 \;\; 0.125]$. The corresponding probability for each state is $[0.331 \;\; 0.626 \;\; 0.043]$ such that the price shock has the mean of zero.

Housing supply elasticity. Housing supply elasticity estimates in Australia are not readily available. Liu and Otto (2014) find that the supply elasticity of houses in Sydney metropolitan areas varies from 0.07 to 0.96, while that of apartments lies between 0.16 to 4.34. To the best of our knowledge, the estimates by Liu and Otto (2014) are the only measure available for the Australian economy. In our baseline model, we set $\varepsilon = 2$. This value is higher than the average estimate reported in Liu and Otto (2014) since the Sydney housing markets are one of the most supply-constrained markets in Australia. For the steady state comparison, we also consider the case in which the supply of housing is perfectly inelastic, $\varepsilon = 0$, a situation where the response to the policy change is fully demand driven, and the other extreme

Table 1: Externally Chosen Parameter Values

	Parameter	Model value	Annual value	Source
r	Risk-free interest rate	0.092	0.018	RBA
m	Mortgage premium	0.118	0.023	RBA
σ	Coefficient of risk aversion	2		Literature
ϕ^b	Trans. cost for buyer (frac. house value)	0.037		Ave. stamp duty
ϕ^s	Trans. cost for seller (frac. house value)	0.03		Ave. agent fee
δ	Depreciation of housing stock	0.104	0.02	SIH
ρ	Persistence of income process	0.65	0.94	HILDA
σ_u	Std. dev. of income innovation	0.44	0.173	HILDA
$h(1)$	Minimum housing size for purchase	0.8		
ε	Housing supply elasticity	2		
ω	Capital gain shock (annual)	$[-0.114 \;\; 0.037 \;\; 0.125]$		SIH
κ_a	Survival probability (age-dependent)			ABS
$\bar{Y}_k, \tau_k, T_k$	Taxation	Refer to text		ATO

where housing supply is highly elastic, $\varepsilon = 6$.[16]

4.2 Calibration via Estimation

The remaining parameters, $\Theta = \{\zeta, \beta, \lambda, \alpha\}$, are calibrated jointly through model estimation. We estimate these parameters using the method of moments approach that matches the model's equilibrium moments with the empirical moments constructed from the SIH and the HILDA survey. The procedure we use is briefly summarized as follows:

Let M_j represents the jth moment in the data, and let $M_j(\Theta)$ represent the corresponding moments generated by the model equilibrium. The task is to find Θ that minimizes the following objective function:

$$L(\Theta) = \arg\min_{\Theta} \sum_{j=1}^{J} \left(M_j - M_j(\Theta)\right)' W \left(M_j - M_j(\Theta)\right) \tag{18}$$

where W is an identity matrix. Minimizing this function requires solving the household's optimization problem and finding equilibrium house price and rent for each trial value of the parameter vector. The solution to (18) is a vector of parameters $\Theta = \{\zeta, \beta, \lambda, \alpha\}$ that are jointly estimated by minimizing the distance between M and $M(\Theta)$. Below, we describe

[16]Housing supply will often be inelastic at least in the short-run due to restrictions such as land constraints and regulation.

Table 2: Calibrated Parameters and Target Moments

	Parameter	Value	Target Moment	Empirical	Model
ζ	Fixed cost of being landlord	0.018	Frac. of landlords	0.172	0.167
β	Discount factor (annual)	0.971	Frac. of H/O with mortgage	0.535	0.557
λ	Utiliy premium for homeowners	1.321	Ave. homeownership rate	0.672	0.667
α	Share of non-durable consumption	0.879	Ave. rent-to-wage ratio	0.144	0.144

how these parameters relate to the model moments and their empirical counterparts.

The fixed cost associated with housing investment, ζ, controls the aggregate landlord rate of the economy. The SIH 2013-14 shows that the landlord rate of across the entire population is 17.2 percent. The discount factor, β, determines the preference towards borrowings so we choose the fraction of homeowners with outstanding mortgages for the target moment. According to the SIH, around 53.5 percent of homeowners had outstanding mortgages. The utility premium parameter, λ, directly influences the average homeownership rate of the economy. The SIH suggests that the homeownership rate for Australia is around 67.2 percent. Finally, the share of non-durable consumption, α, determines households' preference for housing and non-housing consumption. We therefore include the rent-to-wage ratio as a target moment in our estimation. We calculate the rent-to-wage ratio from Waves 1 to 15 of the HILDA survey, which the value is 0.144.

In Table 2, we report the estimated parameter values, lined up with the empirical and resulting model moments that they influence most strongly. First, ζ is estimated to be 0.018 and this gives the landlord rate in the model as 16.7 percent. $\zeta = 0.018$ implies that the annual maintenance cost associated with investment housing is around \$1,253. The value for β is 0.88 which corresponds to the annual discount factor of 0.97. In the model, around 55.7 percent of homeowners have outstanding mortgages. The estimated value of λ is 1.321 and this generates the average homeownership rate of 66.7 percent. The share of non-durables, α, is calibrated to be 0.879. When $\alpha = 0.879$, the model has the average rent-to-wage ratio of 0.144, exactly matching the rent-to-wage ratio found in the HILDA survey.

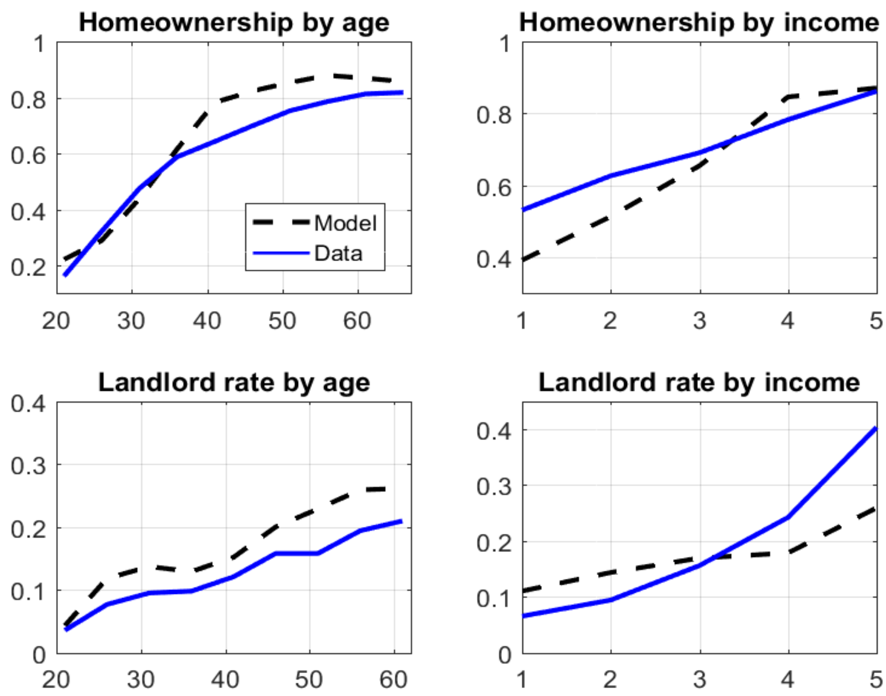

Figure 4: Model vs. Data: Comparison over life-cycle and income quintiles

4.3 Quantitative Properties of Baseline Model

Homeownership and landlord rates. The top left panel of Figure 4 plots the average homeownership rate over the life-cycle. The model is able to produce the pattern of life-cycle homeownership that is seen in the data where the homeownership rate increases from 20.8 percent at age 21 to the peak of 89 percent at age 55. The landlord rate over the life-cycle is displayed in the bottom-right panel of Figure 4. The model tends to over-predict the landlord rate across age, but exhibits an increasing trend which is also observed in the data. The left panels show the homeownership and landlord rates over the income quintile. The model replicates the data reasonably well where both rates increase across the income quintile.

Moments not targeted. We check the external validity of our model using the moments such as ratios of median house value to median income, median loan to median income,

Table 3: Moments not Targeted

Moment	Data	Model
House value to Income Ratio	1.37	1.25
Loan to Income Ratio	0.67	0.69
Loan to Value Ratio	0.49	0.65
Proportion of negatively geared landlords	0.64	0.70

Note: The first three rows of the data column are sourced from SIH 2013-14. The proportion of negatively geared landlords is sourced from Taxation Statistics from 2001 to 2015.

and median loan to median house value ratio. We report the empirical counterparts from the SIH. These moments are not targeted in our estimation. Table 3 shows that the model produces very similar values for these moments to their empirical counterparts. Importantly, the last row of Table 3 shows that the model is able to match the average proportion of negatively geared landlords reported in ATO's Taxation Statistics between 2001 and 2012. Given our research question, it is crucial to generate a significant number of negatively geared landlords in equilibrium. What drives the proportion of negatively geared landlords? It is the capital gains that outweighs the flow loss incurred during investment periods. In our model, we introduce an i.i.d. capital gains shock that allows many homeowners to receive capital gains upon sales. Although the ex-ante expected capital gains is zero, most housing investments generate capital gains ex-post, playing a central role in generating a positive proportion of negatively geared households. The fact the model is able to match this gives additional credibility to our calibration strategy discussed in this section.

5 Removing Negative Gearing

In this section, we present the main result of this paper, the effects of negative gearing on housing price, rent, homeownership rate and household welfare. We do so by comparing the equilibrium outcomes of the baseline economy with that of a counterfactual economy which does not feature negative gearing. The baseline economy is solved with taxes and the taxable income, given by (7). The net rental income in the counterfactual economy follows (8) in

Table 4: Steady state comparison

	Baseline	No NG		
		$\varepsilon = 2$	$\varepsilon = 0$	$\varepsilon = 6$
Price	1.180	1.160	1.138	1.168
Rent	0.164	0.168	0.169	0.168
Price-rent ratio	7.209	6.907	6.725	6.947
Frac. of homeowners	0.667	0.722	0.750	0.721
Frac. of owner-occupiers	0.500	0.584	0.591	0.578
Frac. of landlords	0.167	0.138	0.158	0.143
Frac. of renters	0.333	0.242	0.250	0.279
Ave. mortgage size	0.936	0.712	0.710	0.754
Debt to income ratio	0.356	0.304	0.300	0.301
Ave. expenditure: investment housing	1.676	1.386	1.365	1.405
Frac. of negatively geared investors	0.701	0.505	0.459	0.506
Transfers	0.229	0.236	0.234	0.237
Rental supply (relative to housing supply)	0.263	0.184	0.211	0.192
Housing supply (normalized)	1	0.987	1	0.949

Note: The last two columns provide results for the reformed economy using alternative values of housing supply elasticity, $\varepsilon = 0$ and $\varepsilon = 6$. With inelastic housing supply, the price of housing declines by more since there is no supply response. The homeownership rate in the inelastic economy is higher because the price-to-rent ratio is lower. With a higher elasticity, the price declines by less because the housing supply decreases more than the economy with $\varepsilon = 2$. Other moments of the model are hardly affected by the elasticity.

which landlords are no longer allowed to reduce the total taxable income when negative per-period rental income is realized.

5.1 Steady State

Table 4 compares the effects of negative gearing on house prices, rents and other aggregate statistics across steady states. When negative gearing is repealed, housing prices decrease by 1.7 percent while rents increase by 2.4 percent. The housing prices fall because removing negative gearing takes a significant amount of housing investment out of the property market. Both the proportion of landlords and the amount of resources allocated to housing investment, given by the average expenditure, have fallen significantly after the policy reform. The rent rises mainly because there is a decline in the aggregate supply of rental properties which decreased more than 30 percent relative to that in the baseline economy.

Importantly, removing negative gearing increases the average homeownership rate of the economy from 66.7 percent to 72.2 percent. We provide the following mechanisms for

Table 5: Changes in homeownership and owner-occupier rates (difference in % points)

Age Group	Δ in homeownership rate Q1	Q2	Q3	Q4	Q5	Δ in owner-occupier rate Q1	Q2	Q3	Q4	Q5
35 or below	1.36	1.73	-1.48	-0.31	6.94	1.48	5.48	4.81	11.61	12.16
$36-50$	9.60	7.32	6.67	1.80	1.45	10.44	10.85	13.34	6.47	19.48
$51-65$	6.59	7.02	2.22	2.34	1.81	6.85	4.10	2.59	3.38	10.24
66 or above	12.33	6.73	8.41	4.78	4.51	8.37	5.73	9.90	7.31	10.42

Income Quintile

this. The fall in house price and the rise in rent reduce the price-to-rent ratio in the economy. In our simulation, the ratio falls by 4.2 percent. This has direct implications on housing affordability as the fall in house price lowers both the downpayment requirement for mortgages and the size of mortgages required to purchase a house, making it easier for households to own a home. The simulation suggests that the average size of mortgages held by homeowners decreases by 21 percent. Moreover, the transaction costs associated with selling and buying housing stocks decrease with the lower purchasing price. On the other hand, the rise in rents promotes renters to become homeowners as it increases the cost of renting.

The improvement in homeownership is observed most predominantly among poor households. The impact of the policy change on home affordability is largest for these households because the lower housing price and higher lump-sum transfer allow those poor households who were at the margin of being homeowners to achieve housing tenure. In Table 5, we report the percentage point change in homeownership and owner-occupier rates by age group and income quintile. For the sake of exposition, we group age cohorts into four categories including 35 or below, $36-50$, $51-65$, and 66 or above. Eliminating negative gearing increases the homeownership rate for most groups of households. Note that negative values shown in the left half of Table 5 (changes in homeownership rate) are driven by landlords who decide to become renters after the policy change. As shown in the right half of Table 5, the owner-occupier rate increases ubiquitously for all age groups and income quintiles. In particular, such an increase is most prominent for households who were relatively young and poor. For instance, the homeownership rate for the age group under 35 and the lowest

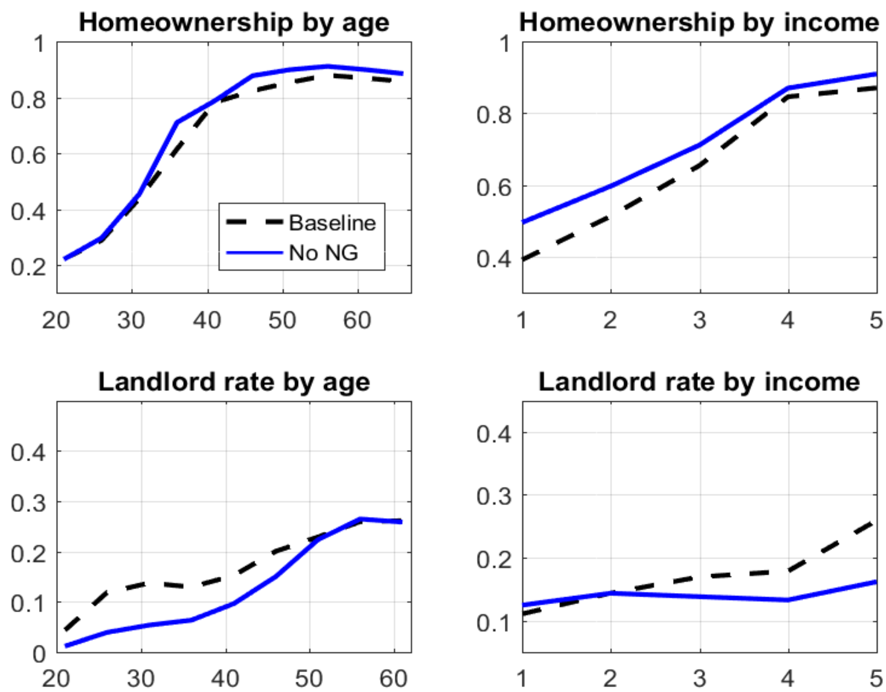

Figure 5: Baseline vs. No negative gearing: Comparison over life-cycle and income quintiles

income quintile increase by 26.4 percent (1.4 percentage points). Also, the owner-occupier rates for the age group under 35 and the first and second income quintiles increases 60 percent (1.5 percentage points) and 104 percent (5.8 percentage points) respectively. We also find that these changes are greater for young and mid-aged households. The top right panel of Figure 5 also shows that the homeownership rate for the lower income quintiles increased proportionately more than that experienced by households at higher income quintiles.

How does housing allocation shift between high and low income households? To answer this question, we look at the percentage change in housing services consumption and the purchase of housing assets for households at each income quintile. The allocation of housing stocks shifts from the high income to low income households. Figure 6 shows that consumption for housing services improves for every income quintile. For instance, in the counter-factual steady state, households in the first income quintile consume housing services around 9 percent more relative to the baseline steady state. Similarly, the aggregate housing stocks purchased by those households in the counter-factual economy is around 17

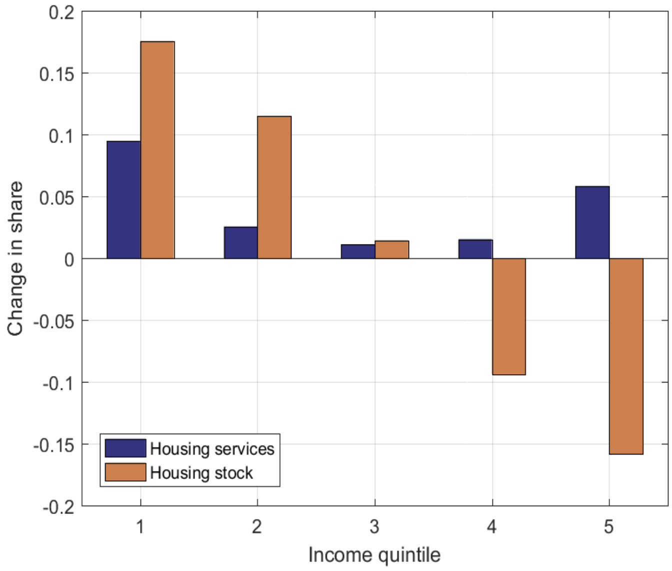

Figure 6: Change in steady state housing share

percent higher than the total purchase made by households in the first income quintile from the baseline economy. Low income households consume more housing services as some of them, after the reform, become owner-occupiers and live in bigger houses. High income households also consume more housing services because the policy reform reduces incentives for them to lease unused housing assets. Instead, these households use them for their own consumption. Shifts in the allocation of housing asset is asymmetrical. As Figure 6 plots, households at lower income quintiles increase the housing purchase since it is now relatively cheaper to own a house for the reasons we discussed above. Households at the 4th and 5th income quintiles hold less housing assets after the removal of negative gearing primarily because the policy change would discourage them to invest in the housing market.

5.2 Effects on Landlord Composition

Thus far, we have discussed the effects of negative gearing on the aggregate statistics including house prices, rent and homeownership rates. Eliminating negative gearing improves housing affordability by cooling down the housing investment. In this subsection, we discuss how the policy reform would alter the composition of housing investors.

Table 6: Changes in landlord rate (difference in % points)

Age Group	Income Quintile Q1	Q2	Q3	Q4	Q5
35 or below	-0.12	-3.75	-6.29	-11.92	-5.22
36 − 50	-0.84	-3.53	-6.67	-4.66	-18.03
51 − 65	-0.26	2.93	-0.38	-1.04	-8.43
65 or above	3.95	1.00	-1.49	-2.53	-5.91

The bottom panels in Figure 5 depict the landlords rates over the life-cycle (left) and income quintile (right). The left panel shows that the fraction of landlords is significantly lower for households under age 50 in the counterfactual economy. Young landlords have relatively low levels of wealth and rely on borrowings to finance housing investments. Essentially, they are the group of households who would have benefited the most from negative gearing. Likewise, as illustrated on the right, the reduction in housing investment is mostly due to the less investment undertaken by high income households. The reform therefore drives young landlords with high earnings out of the market for housing investment. Table 6 shows the percentage point change in the average landlord rates by age groups and income quintiles. Consistent with our interpretation, the magnitude of the decrease in landlord rates is largest for households who are young (under age 45) and rich (4th and 5th income quintiles).

Similarly, landlords at the upper income quintiles respond most sensitively to the repealing of negative gearing. In the first row of Table 7 shows that the policy reform reduces the total amount of housing investment undertaken by landlords at 4th and 5th income quintiles by more than 50 percent, and the magnitude of the decrease is increasing in income quintiles. The progressive nature of the Australian tax system leads those rich landlords to pay proportionately more tax than those who are relatively poor. This provides them with more incentives to invest in bigger houses when negative gearing is present because the marginal benefit from tax deduction is larger.

We also provide the evidence on the borrowing behavior of landlords. The second row of Table 7 shows that the decrease in the mortgage holdings by landlords is largest for the

Table 7: Other effects on landlords

	$Q1$	$Q2$	$Q3$	$Q4$	$Q5$
% change in total housing investment **by income quintiles**	-4.89	-2.89	-22.00	-46.24	-64.04
% change in landord's mortgage holdings **by income quintiles**	-16.15	-20.14	-34.54	-53.41	-66.70
% change in landlord rates **by mortgage quintiles**	-10.76	-11.10	-21.98	-17.47	-21.61

4th and 5th quintiles. The last row of Table 7 supports this result by showing that the fall in landlord rates is also larger for higher quintiles of mortgage holdings by landlords. The landlord rates for the 4th and 5th quintiles decrease approximately 1.5 to 2 times more than that for the first quintile, suggesting that landlords move down along the mortgage quintiles. The policy reform mitigates the borrowing activities of landlords and makes them to hold less debt than the baseline economy.

These predictions reconcile the recent trend in landlord compositions shown in Section 2 in which the share of households with investment housing loans increased more sharply for the group of landlords who are young and rich. Our model predicts that such landlords would respond most sensitively, reducing the amount of mortgage holdings and investing less in the property market when negative gearing is repealed.

5.3 Welfare Analysis

We now turn to the welfare analysis. Following the existing literature, welfare is measured using the notion of consumption equivalence variation (CEV).[17] In accounting for the magnitude of welfare gain or loss, we calculate the percentage change in the current consumption of non-durable good that equates the expected discounted utility of the counterfactual

[17] See Conesa, Kitao, and Krueger (2009) and Hong and Ríos-Rull (2012) for a welfare discussion of more general life-cycle models. For the life-cycle housing literature, see Nakajima (2012), Chambers, Garriga, and Schlagenhauf (2009b), and Floetotto, Kirker, and Stroebel (2016) where the authors take a similar approach to the method used in this paper.

economy with that of the baseline economy. In our model, households are heterogeneous in terms of their financial position, housing assets, age and earnings, as summarized in the state vector x. So a welfare analysis requires us to find the consumption equivalence variation for each pair of *identical* households characterized by a particular x from the baseline and counterfactual economies. Formally, we solve the *cev* for each x (and transform them into percentage changes) such that:

$$V(x)^{nong} = u\left(c^*(x) + cev, \tilde{h}^*(x)\right) + \beta\kappa_a \mathbb{E}_{z'|z}\left[V(x'^*(x))^{ng}\right] \quad \text{for any} \quad x \equiv (a, s, h, z) \tag{19}$$

where $V(x)^{ng}$ and $V(x)^{nong}$ denote the value functions with and without negative gearing. So the LHS of (19) is the expected discounted utility of a household in the economy without negative gearing, and the RHS is that of the same household living in the baseline economy with $c^*(x)$, $\tilde{h}^*(x)$ and $x'^*(x)$ being the optimal decision rules in the baseline economy. Our measure of welfare can be interpreted as the percentage change in non-durable consumption required by a household in the baseline economy to ensure he is as well off as a household with the same state variables in the reformed economy. A positive value for consumption equivalence variation suggests that households are better off in the reformed economy, implying that repealing negative gearing improves the welfare. Note that our analysis is based on the unexpected change in the policy that does not allow households to re-optimize their decision in future periods.

Removing negative gearing improves the aggregate welfare. Figure 7 displays a kernel density plot of CEVs across households from the two stationary equilibria. Eliminating negative gearing generates the average welfare gain of 1.5 percent for the economy. Also, the median welfare gain is 4.7 percent and around 76 percent of households prefer to live in an economy without negative gearing. We provide two reasons why welfare improves for the economy. First, negative gearing is a policy that largely benefits landlords. In our baseline economy, approximately 17 percent of households are landlords and of those, 70 percent are negatively geared. This means that less than 13 percent of the entire population are directly

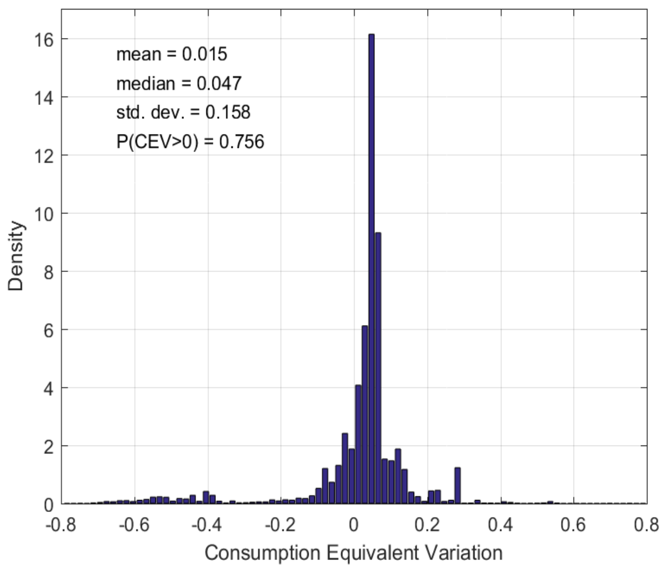

Figure 7: Kernel density of consumption equivalent variation

influenced by the removal of negative gearing. The benefit of lower homeownership costs out-weighs the increased tax burden of landlords. Second, the government's tax revenue increases when negative gearing is repealed, increasing the amount of lump-sum transfers. The redistribution of the government revenue is important as it compensates renters for higher rents, owner-occupiers for lower house prices and landlords for higher tax burden. It particularly benefits young and low income households who would rely proportionately more on transfer payments. Table 8 provides the average welfare across age group and income quintiles. We can interpret CEVs in Table 8 as follows. For instance, the value in the top left corner suggests that an average household under age 35 living in the baseline economy needs to increase his current consumption by 5.3 percent in order for him to be indifferent to the life quality he would have received in the reformed economy. The gain in welfare is observed for most age groups and income quintiles. The median CEVs for all subgroups are positive. In particular, welfare of households in the young age group (35 or below) significantly improves. Most households at these ages become homeowners for the first time and thus benefit from the lower cost of homeownership.[18] The last row of Table 8

[18]Both HILDA and SIH report that the average age of the first home buyer in Australia is 29.

Table 8: Welfare Effects across Age and Income

Age Cohort	Mean CEV						Median CEV					
	Income Quintile											
	$Q1$	$Q2$	$Q3$	$Q4$	$Q5$	W.A.	$Q1$	$Q2$	$Q3$	$Q4$	$Q5$	W.A.
35 or below	0.053	0.060	0.046	0.035	0.055	0.050	0.060	0.057	0.062	0.051	0.056	0.059
$36-50$	-0.018	0.053	0.007	0.010	-0.018	0.018	0.029	0.055	0.048	0.048	0.045	0.049
$51-65$	0.046	-0.047	-0.026	-0.005	-0.023	-0.023	0.047	0.037	0.033	0.033	0.026	0.034
66 or above	0.005	0.033	0.025	-0.034	0.002	0.012	0.016	0.029	0.013	0.015	0.016	0.018
W.A.	0.025	0.027	0.015	0.001	0.003		0.042	0.048	0.044	0.037	0.038	

Table 9: Welfare effects by housing tenure status

Initial Housing Tenure	Mean CEV	Median CEV	Std. dev. CEV	$P(CEV > 0)$
Renter	0.049	0.051	0.115	0.776
Owner-occupier	-0.015	0.036	0.163	0.776
Landlord	-0.099	-0.018	0.249	0.455

also shows that the average welfare gain is regressive across income quintiles.

How does welfare differ among renters, owner-occupiers and landlords? In Table 9, we provide the welfare effects by the initial housing tenure status. The median CEV of renters and owner-occupiers are 0.051 and 0.036 respectively and around 78 percent of them are better off after the policy reform. Renters are able to consume more housing services and non-durable consumption goods due to higher transfers funded by taxes collected from landlords. The increase in transfers out-weighs the small increase in rents. Owner-occupiers also prefer the alternative steady state since the cost of homeownership is lower. However, landlords are worse off. The median CEV for landlords is -0.018 and approximately 55 percent prefer the status quo. These landlords used to purchase the large amount of housing assets, lease out unused stocks and take advantage of tax deductions in the baseline economy. Also, the increase in transfers benefit them the least as earnings for most landlords are high.

We further examine the welfare effects by housing tenure and income quintile. Table 10 displays that landlords in higher income quintiles are clearly losers of the policy change. Due to the progressive tax system, the marginal benefit of tax deduction from negative gearing is higher for these landlords. In our simulation, the average size of investment prop-

Table 10: Welfare effects by housing tenure status and income quintiles

Initial Housing Tenure	Median CEV					$P(CEV > 0)$				
	Income Quintile									
	$Q1$	$Q2$	$Q3$	$Q4$	$Q5$	$Q1$	$Q2$	$Q3$	$Q4$	$Q5$
Renter	0.059	0.057	0.051	0.049	0.053	0.812	0.782	0.732	0.915	0.944
Owner-occupier	0.025	0.036	0.036	0.037	0.039	0.672	0.704	0.782	0.788	0.858
Landlord	0.027	0.009	-0.014	-0.072	-0.363	0.718	0.544	0.475	0.374	0.106

Table 11: Welfare effects by housing tenure status and age group

Age Group	Median CEV			$P(CEV > 0)$		
	Initial Housing Tenure Status					
	Renter	Owner-occupier	Landlord	Renter	Owner-occupier	Landlord
Under 35	0.056	0.056	-0.092	0.777	0.808	0.286
$36-50$	0.051	0.048	-0.081	0.794	0.841	0.418
$51-65$	0.049	0.033	-0.018	0.846	0.768	0.448
Above 66	0.024	0.013	0.030	0.689	0.675	0.664

erties purchased by landlords in the fourth and fifth income quintiles decrease by 29 and 41 percent which are much higher than that of landlords in other income quintiles. Scrapping the tax concession disincentivizes rich landlords from housing investment and make them worse off. On the other hand, landlords at lower income quintiles prefer to live in the reformed economy because they face lower marginal tax rates so that the gains from an increase in rental receipts and higher transfer payments exceed the loss from the tax concession.

Finally, we provide the welfare effects across housing tenure and age group in Table 11. The biggest welfare loss occurs for landlords who are relatively young. The median CEV for landlords who are under 35 is -0.082 while that of those between age $35-50$ is -0.081, and around 71 and 58 percent of young landlords in those two age groups suffer from the welfare loss. The young landlords are worse off because most of them rely on borrowings and incur rental loss during the earlier stage of their housing investment. Essentially, they are the group of households who would have benefited the most from negative gearing. As displayed in Figure 8, landlords in the first two age groups show the larger cut on the size of houses that they invest in, since the policy reform no longer allow them to benefit from lower tax obligations by investing in the housing market.

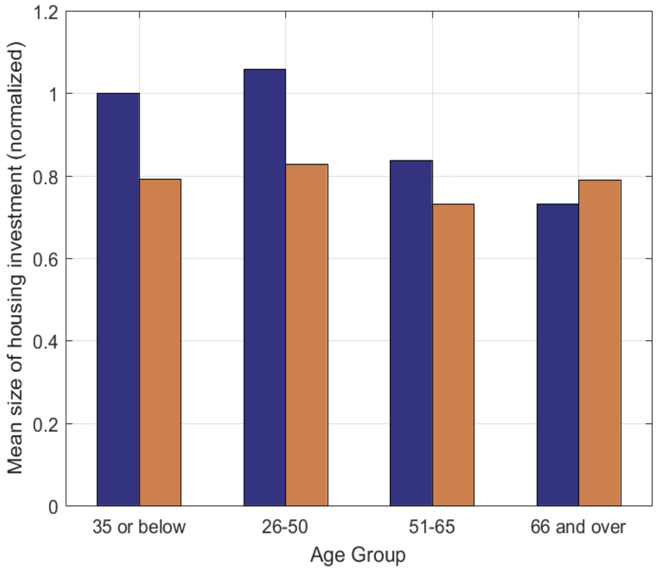

Figure 8: Average size of investment properties by age group

6 Conclusion

Subsidizing the supply of rental properties by providing tax credits to landlords is a common housing policy in many economies. In this paper, we have built a heterogeneous agents overlapping generations model to analyze and quantify the effects of negative gearing - a tax concession that allows landlords to deduct housing investment losses from their gross income - on house prices, rents, allocations and welfare for the Australian economy.

Our model shows that, in equilibrium, repealing negative gearing decreases house prices, increases rents thereby improves a home affordability of Australian households. As a result, the average homeownership rate increases. The responses to the policy reform are different along the dimension of household age and earnings. The rise in homeownership rate after the policy reform is larger for young households who were relatively poor. Elimination of negative gearing helps poor households as lower house prices allow them to consume the bigger amount of housing services. The model also shows that eliminating negative gearing takes young landlords who were rich enough to meet a downpayment requirement for investment properties away from the market. This reconciles a recent trend in the property market that there has been a rise in investment housing debt holdings by young and rich households who would have benefited the most from negative gearing concessions.

The aggregate welfare for the economy improves upon the repeal of negative gearing. Around 80 percent of households are better off after the policy reform. However, the welfare effects on each household depends on their state at the time of the reform. Our analysis suggests that the group of households hurt by the policy change is landlords who are young and rich since most of them rely on mortgages to finance their housing investment. The welfare loss for these landlords is exacerbated by the progressive tax system.

There are a number of extensions to this paper. First, the current model focus on a stationary equilibrium where ex-ante expected capital gains on housing asset is zero. Given the recent boom in the Australian housing market, it is natural to embed a housing price appreciation by changing the model structure to non-stationary with aggregate shocks to house prices. Second, our paper only discusses the implications on eliminating negative gearing. It would also be worth considering some partial restrictions on negative gearing such as allowing tax deductions for mortgage interest payments only. Exploring implications of the variation of negative gearing would be another policy scenario that is worth pursuing for future research.

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Appendix

A0. Policy experiment without redistribution

In this section of appendix, we solve the model by shutting down the redistribution channel of government revenue created by eliminating negative gearing. Below, we provide the steady state and welfare results by simulating the counterfactual economy with the same level of transfer payments to the baseline economy. That is, the government uses the additional tax revenue for its own consumption which does not affect the decision of households.

Table 12: Steady state comparisons with and without redistibution

	Baseline	No NG (redist)	No NG (no redist)
Price	1.180	1.160	1.161
Rent	0.164	0.168	0.168
Price-rent ratio	7.209	6.907	6.911
Frac. of homeowners	0.667	0.722	0.715
Frac. of owner-occupiers	0.500	0.584	0.583
Frac. of landlords	0.167	0.138	0.132
Frac. of renters	0.333	0.278	0.285
Rental supply (relative to housing supply)	0.263	0.184	0.178
Aggregate housing supply (normalized)	1	0.987	0.987
Transfers	0.229	0.236	0.229
Debt to income ratio	0.356	0.304	0.305

The last column of Table 12 shows that the steady state moments of the counterfactual economy without redistribution are very similar to that in the economy with redistribution. The increase in lump-sum transfers hardly change the price and quantity effects of negative gearing in steady states.

Turning to the welfare analysis, we find that there is a welfare loss when the government does nothing with the additional revenue created by repealing negative gearing. The mean of consumption equivalence variation, defined the same way as in the main body of the paper, is -2.6 percent. Around 68 percent of households are worse off. The fall in house prices hurts most homeowners especially elders who would be downsizing their dwellings.

Renters are worse off due to higher rents. Table 13 shows that the welfare loss is large for landlords while it is smaller for renters and owner-occupiers. The lower homeownership cost helps some renters (owner-occupiers) with housing purchase (upgrade) but the majority of them prefer the status quo if there is no redistribution.

Tables 14 and 15 show the welfare effects by housing tenure across income quintiles and age group. It is worth nothing that almost every landlord in the top income quintile prefer the status quo while more than 50 percent of high income owner-occupiers marginally prefer the counter-factual economy. Young owners-occupiers also prefer the counterfactual economy since the lower house prices help them to climb up a housing ladder more easily.

Table 13: Welfare effects by housing tenure status

Initial Housing Tenure	Mean CEV	Median CEV	Std. dev. CEV	$P(CEV > 0)$
Renter	0.007	-0.007	0.111	0.290
Owner-occupier	-0.053	-0.008	0.164	0.385
Landlord	-0.141	-0.057	0.251	0.265

Table 14: Welfare effects by housing tenure status and income quintiles

Initial Housing Tenure	Median CEV					$P(CEV > 0)$				
	Income Quintile									
	$Q1$	$Q2$	$Q3$	$Q4$	$Q5$	$Q1$	$Q2$	$Q3$	$Q4$	$Q5$
Renter	-0.009	-0.004	-0.007	-0.016	-0.002	0.310	0.423	0.224	0.111	0.252
Owner-occupier	-0.020	-0.016	-0.010	0.001	0.006	0.268	0.267	0.280	0.519	0.642
Landlord	-0.024	-0.028	-0.064	-0.107	-0.346	0.169	0.298	0.308	0.203	0.036

Table 15: Welfare effects by housing tenure status and age group

Age Group	Median CEV			$P(CEV > 0)$		
	Initial Housing Tenure Status					
	Renter	Owner-occupier	Landlord	Renter	Owner-occupier	Landlord
Under 35	-0.005	0.020	-0.123	0.308	0.753	0.286
$36-50$	-0.020	0.004	-0.128	0.264	0.551	0.272
$51-65$	-0.017	-0.011	-0.054	0.219	0.309	0.241
Above 66	-0.009	-0.017	-0.004	0.317	0.233	0.487

A1. Estimation of Income Process

In this part of appendix, we provide the empirical estimates of income process using the Australian household panel data – Household, Income and Labour Dynamics in Australia (HILDA).

Data. The data are sourced from the HILDA, a longitudinal survey of Australian households which started in 2001. The HILDA survey is an ideal data set that enables us to investigate the dynamics of household income over the life-cycle, and to this date, 15 Waves are available. The survey contains information of labor market activities, socio-economic and demographic factors that are standard in a typical household survey. To begin with, we use all observations in Waves from 1 to 15.

For the income variable we use the gross income reported at the individual level. In HILDA, the gross income captures income sources from labor, business, investment, private and public pensions, and government transfers. Since investment decisions are endogenous in our model, we subtract the investment income component from the total gross income. From this, we further trim the data set using the following criteria:

1. Male head of household;
2. Age between 21 and 64 years old;
3. Positive labor income;
4. Full-time workers; and
5. 10 consecutive years of appearance.

With the above restrictions, we end-up with the total of 1,514 individuals and 19,714 observations.

Model specification. The specification of labor income for individual i of age a is expressed as:

$$\log y_{i,a} = \gamma_a + z_{i,a} + \varepsilon_{i,a}$$

where γ_a is a deterministic component of income that depends on individuals' age; $z_{i,a}$ is a persistent idiosyncratic component; and $\varepsilon_{i,a}$ is a transitory shock component of income. The persistent idiosyncratic component follows an AR(1) process as below.

$$z_{i,a} = \rho z_{i,a-1} + u_{i,a} \quad u_{i,a} \sim (0, \sigma_u^2)$$

The above earnings process requires estimation of two components: (1) deterministic, γ_a and (2) persistent and transitory shocks. The estimation of the deterministic component is relatively straightforward. The deterministic component captures the income profile that is common to all individuals in a particular age group, and also removes any predictable patterns of the income process. To begin with, we consider a standard Mincerian regression of the following form, run separately year-by-year.

$$\log Y_{i,a,t} = \beta' X_{i,a,t} + \hat{y}_{iat} \tag{20}$$

where $Y_{i,a,t}$ is an annual gross income without any investment incomes. To remove any predictable changes in earnings, we include the term $X_{i,a,t}$ which captures observable demographics such as age, education and race. The last term $\hat{y}_{i,a,t}$ summarizes residuals of the regressions. The deterministic component can then be traced out using the average log income for each age group a and is fitted to a fourth-order polynomial function in age.

Residual process. We assume that the process is *stationary*. Although we obtain residuals year-by-year, these residuals are averaged across years, i.e. $\hat{y}_{i,a} \equiv \overline{\hat{y}}_{i,a,t}$. From this point onwards, we drop the subscript t. Identification and estimation of nonstationary precess are more complicated, see Heathcote, Storesletten, and Violante (2014) for example. The

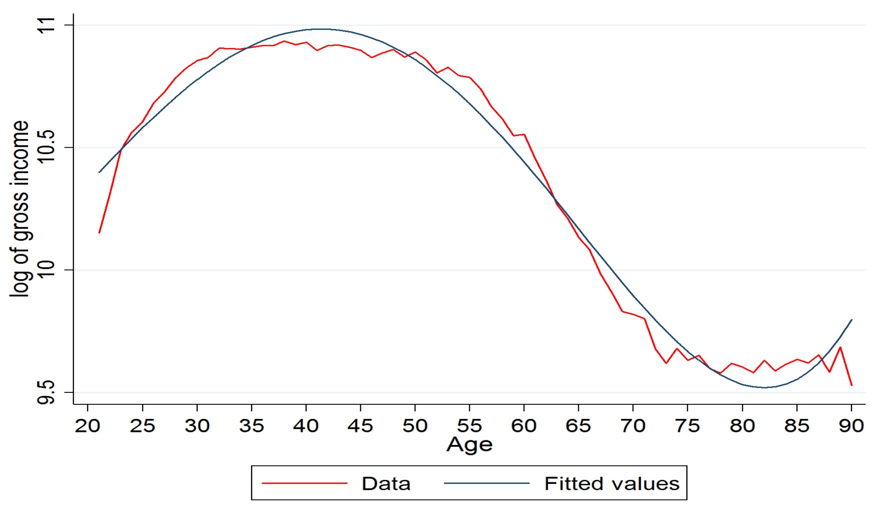

Figure 9: Deterministic component

specification of the process of residual dispersion can then be written as

$$\hat{y}_{i,a} = z_{i,a} + \varepsilon_{i,a} \tag{21}$$

$$z_{i,a} = \rho z_{i,a-1} + u_{i,a} \tag{22}$$

where

$$\varepsilon_{i,a} \sim \text{IID}(0, \sigma_\varepsilon^2); \quad u_{i,a} \sim \text{IID}(0, \sigma_u^2); \quad z_{i,0} \sim \text{IID}(0, \sigma_{z,0}^2)$$

and

$$\varepsilon_{i,a} \perp u_{i,a} \perp z_{i,0},$$

The parameters to be estimated are grouped into $\theta = \{\rho, \sigma_\varepsilon^2, \sigma_u^2, \sigma_{z,0}^2\}$.

Identification. We follow identification procedures discussed in Guvenen (2009) and Storesletten, Telmer, and Yaron (2004). Identification in levels is based on the following definitions of variances and covariances.

$$
\begin{aligned}
var(\hat{y}_{i,0}) &= \sigma_{z,0} + \sigma_\varepsilon && \text{for } a = 0 \\
var(\hat{y}_{i,a}) &= var(z_{i,a}) + \sigma_\varepsilon && \text{for } a > 0 \\
var(z_{i,a}) &= \rho^2 var(z_{i,a-1}) + \sigma_u \\
cov(\hat{y}_{i,a}, \hat{y}_{i,a-j}) &= cov(z_{i,a}, z_{i,z-j}) && \text{for } j > 0 \\
cov(z_{i,a}, z_{i,a-j}) &= \rho^j var(z_{i,a-j})
\end{aligned}
$$

With these in hand, we can formulate the parameter identification as follows. First, the AR(1) coefficient or the persistent parameter ρ is identified from the slope of the covariance at lags.

$$
\frac{cov(\hat{y}_{ia}, \hat{y}_{i,a-2})}{cov(\hat{y}_{i,a-1}, \hat{y}_{i,a-2})} = \frac{\rho^2 var(z_{i,a-2})}{\rho var(z_{i,a-2})} = \rho
$$

The variance of transitory component, σ_ε^2 is identified from the difference between variance and covariance

$$
var(\hat{y}_{i,a-1}) - \rho^{-1} cov(\hat{y}_{ia}, \hat{y}_{i,a-1}) = var(\eta_{i,a-1}) + \sigma_\varepsilon - var(\eta_{i,a-1})
$$

and the variance of initial persistent component, $\sigma_{z,0}^2$ can be obtained residually from σ_ε^2 and $var(y_i, 0)$. Finally, the variance of error term in the AR(1) process, σ_u^2 is identified from the following.

$$
\begin{aligned}
var(\hat{y}_{i,a-1}) - cov(\hat{y}_{ia}, \hat{y}_{i,a-2}) - \sigma_\varepsilon^2 &= \rho^2 var(\eta_{i,a-2}) + \sigma_u^2 + \sigma_\varepsilon^2 - \rho^2 var(\eta_{i,a-2}) - \sigma_\varepsilon^2 \\
&= \sigma_u^2
\end{aligned}
$$

Therefore, the identification of parameters are achieved using two lags. In our case, the model is largely identified since the HILDA survey is available for 15 waves. Also, the parameters are tightly estimated because the number of individuals in the panel is large. In our baseline sample, there are 1,592 individuals.

Estimation. Our sample consists of the unbalanced panel of individuals aged $a = 1, ..., A$. We define a $A \times 1$ vector for every individual $i = 1, ..., I$.

$$\mathbf{d}_i = \begin{pmatrix} d_{i,1} \\ ... \\ d_{i,A} \end{pmatrix}$$

where $d_{i,a} \in \{0, 1\}$ is an indicator variable for whether individual i is present at age a in the sample. Similarly, define a $A \times 1$ vector of residual earnings observations as

$$\mathbf{y}_i = \begin{pmatrix} \hat{y}_{i,1} \\ ... \\ \hat{y}_{i,A} \end{pmatrix}$$

Since the panel is unbalanced, we must set the missing elements to zero. Now, let

$$\mathbf{Y} = \sum_{i=1}^{I} \mathbf{y}_i \mathbf{y}_i' \quad \mathbf{D} = \sum_{i=1}^{I} \mathbf{d}_i \mathbf{d}_i'$$

The covariance of earnings is then a $A \times A$ symmetric matrix, $\mathbf{C}$, computed as the element by element division between $\mathbf{Y}$ and $\mathbf{D}$

$$\mathbf{C} = \frac{\mathbf{Y}}{\mathbf{D}}$$

The construction of covariance matrix $\mathbf{C}$ is as follows:

$$
\mathbf{C}(\theta) = \begin{bmatrix}
c_{1,1} & c_{1,2} & \cdots & c_{1,j} & \cdots & c_{1,A} \\
c_{2,1} & c_{2,2} & & \cdots & \cdots & c_{2,A} \\
\vdots & & \ddots & & & \vdots \\
c_{j,1} & & & \ddots & & c_{j,A} \\
\vdots & & & & c_{A-1,A-1} & \vdots \\
c_{A,1} & \cdots & \cdots & c_{A,j} & \cdots & c_{A,A}
\end{bmatrix}
$$

in which each element of $\mathbf{C}(\theta)$ can be recovered from the moment conditions of variance and covariance shown above. For instance, the first column of $\mathbf{C}(\theta)$ can be expressed as follow

$$
\mathbf{C}_{\theta}(1) = \begin{pmatrix}
var(z_{i,1}) + \sigma_{\varepsilon}^2 \\
\rho var(z_{i,1}) \\
\vdots \\
\rho^{j-1} var(z_{i,j-1}) \\
\rho^{A-1} var(z_{i,A-1})
\end{pmatrix}
$$

The second column is given by

$$
\mathbf{C}_{\theta}(2) = \begin{pmatrix}
\rho var(z_{i,1}) \\
var(z_{i,2}) + \sigma_{\varepsilon}^2 \\
\vdots \\
\rho^{j-2} var(z_{i,j-2}) \\
\rho^{A-2} var(z_{i,A-2})
\end{pmatrix}
$$

and the same process goes on until Ath column. Each entry of $\mathbf{C}$ is the cross-sectional covariance of earnings at ages (p, q). Next, take the upper triangular portion of $\mathbf{C}$ and vectorize it into an $A(A+1)/2 \times 1$ vector

$$
\widehat{\mathbf{M}} = vech\left(\mathbf{C}^{UT}\right)
$$

Let $\mathbf{M}(\theta)$ be the theoretical counterpart of $\widehat{\mathbf{M}}$. The moment condition is then given by

$$\mathbb{E}[\widehat{\mathbf{M}} - \mathbf{M}(\theta)] = 0$$

The standard estimation strategy in the literature is to use a Minimum Distance Estimator (MDE) proposed by Chamberlain (1984). The goal is to choose the parameter values that minimize the distance between empirical and theoretical moments. The MDE is a solution to

$$\min_{\theta} \left[\widehat{\mathbf{M}} - \mathbf{M}(\theta)\right]' \Omega \left[\widehat{\mathbf{M}} - \mathbf{M}(\theta)\right] \tag{23}$$

where Ω is a weighting matrix.

Weighting matrix and standard errors. Chamberlain (1984) claims that the vector of covariance, $\widehat{\mathbf{M}}$ has an asymptotic variance of the form

$$\mathbf{V} = \frac{\sum_{i=1}^{I} (\widehat{\mathbf{M}} - \widehat{\mathbf{M}}_i)(\widehat{\mathbf{M}} - \widehat{\mathbf{M}}_i)'}{\mathbf{ss}'}$$

where $\widehat{\mathbf{M}}$ defined as above; $\widehat{\mathbf{M}}_i$ is a vector that contains the distinct elements of the cross-product matrix $\mathbf{y}_i\mathbf{y}_i'$ and $\mathbf{V}$ is a $A(A+1)/2 \times A(A+1)/2$ matrix. Similarly, $\mathbf{s} = vech(\mathbf{D}^{UT})$. Chamberlain (1984) shows that the optimal weighting matrix Ω is $\mathbf{V}^{-1}$. However, Altonji and Segal (1996) argue that there is a small sample bias in parameter estimates based on Ω and recommend using (i) $\Omega = I$ (equally weighted estimator) where I is an identity matrix or (ii) $\Omega = diag(\mathbf{V}^{-1})$ (diagonally weighted estimator). Given that, we choose the first one, an equally weighted estimator.

Once we estimate the asymptotic variance, the computation of standard errors is straightforward. The standard errors of estimates are computed as below.[19]

$$\widehat{se}(\hat{\theta}) = \left(\mathbf{G}'\Omega\mathbf{G}\right)^{-1} \mathbf{G}'\Omega\mathbf{V}\Omega\mathbf{G} \left(\mathbf{G}'\Omega\mathbf{G}\right)^{-1} \tag{24}$$

[19] An alternative way of estimating standard errors is to use a bootstrap method. This method however is computationally intensive because it requires sample replications of around 500 times and carry out the structural estimation for each replication.

Table 16: Estimates of income process using HILDA

	10 consecutive	5 consecutive
ρ	0.9407	0.9557
	(0.0078)	(0.0061)
σ_u^2	0.0302	0.0259
	(0.0001)	(0.0000)
$\sigma_{z,0}^2$	0.1376	0.1678
	(0.0003)	(0.0000)
σ_ε^2	0.0805	0.1405
	(0.0026)	(0.0052)
No. of individuals	1541	3341

Note: The model is estimated using the minimum distance method. Asymptotic standard errors are reported in parentheses.

where **G** is the $A(A+1)/2 \times n$ Jacobian matrix of $\mathbf{M}(\theta)$ evaluated at the estimated parameter values. The letter n represents the number of estimated parameters in our statistical model.

Result. In the second column of Table 16, we report the results using the baseline sample. The persistent component, ρ is slightly lower than a random walk process. The results also suggest that the variance of transitory component is higher than that of the persistent component, consistent with the findings by Chatterjee, Singh, and Stone (2015). We also provide in the last column of Table 16 the results based on 5 consecutive years of appearance. When we relax such a restriction on the consecutive years of appearance, we observe slightly higher persistence and lower variances of both persistent and transitory components.

Simulation. Since the HILDA survey is available for only 15 years, it lacks the sufficient time lags to estimate parameters of interest, especially when we need to calibrate our model in which one period accounts for five years.[20] Here, we introduce a simulation technique that enables us to approximate earnings process parameters with any model periods.

[20] Although the re-interview rate in HILDA is reasonably high, only a few households remain in the survey for the entire 15 years of the survey period.

We follow the procedure below to obtain the panel of model implied income. This simulation provides us with a distribution of income that has both cross-sectional and time-series properties implied by the annual parameter estimates.

1. Draw an initial sample of 5,000 individuals, entering the model economy at the age of 21. Also we assume that $z_{i,0} = 0$
2. For each individual and period:
   (a) Draw a death shock. This shock comes from the binomial distribution where the survival probabilities are obtained from the Life Table published by the ABS.
   (b) If survive, continue with the income process specified above.
   (c) If die, replace this individual with a new individual entering the model with age 21. The new individual starts her life-cycle from this period, as noted in (a) and (b).
3. Continue this process for 120 periods. It gives us the unbalanced panel consists of 600,000 observations and 20,521 individuals exiting the panel at different ages.

After obtaining the large panel of income data, we perform the MDE for each model period. For brevity, we provide the estimates for 2, 3, 4, and 5 years. These estimates provide a useful source for income process calibrations in our income process. The simulated data can also be used to estimate income process parameters for any period. The results are reported in Table 17. The estimates for the AR(1) coefficient become lower as the number of model period increases. In contrast, the variance of idiosyncratic component, σ_u^2, increases as the number of model period increases. These observations make intuitive sense as earnings are less persistent (lower ρ) and more volatile (higher σ_u^2) for longer periods. It thus suggests that the mean reversion becomes increasingly a more important determinant in earnings dynamics as we increase the number of periods, and that a random walk specification is not sufficient to understand the income process for models with longer time horizons. We also provide the annual estimates using the simulated data. Encouragingly, the key parameters,

Table 17: Estimates of income process using simulated data

	Actual	1 year	2 year	3 year	4 year	5 year
ρ	0.9407	0.9200	0.8367	0.7675	0.7261	0.6404
	(0.0078)	(0.0001)	(0.0035)	(0.0006)	(0.0003)	(0.0003)
σ_u^2	0.0302	0.0434	0.1030	0.1525	0.1948	0.2357
	(0.0001)	(0.0001)	(0.0006)	(0.0015)	(0.0028)	(0.0057)
$\sigma_{z,0}^2$	0.1376	0.2185	0.1775	0.1337	0.0640	5.1×10^{-7}
	(0.0003)	(0.0004)	(0.0023)	(0.0058)	(0.0094)	(0.0022)
σ_ε^2	0.0805	0.0369	9.9×10^{-9}	6.8×10^{-7}	1.3×10^{-9}	0.0041
	(0.0026)	(0.0015)	(0.0034)	(0.0060)	(0.0096)	(0.0137)
No. of individuals	1,541	18,566	18,283	17,623	16,570	15,048

Note: The data are generated from simulation. The model is estimated using the minimum distance method. Asymptotic standard errors are reported in parentheses.

ρ and σ_u^2 are close to the actual estimates reported in Table 1, reinforcing the credibility of our simulation procedure.

We also run an additional simulation to support that the above simulation is sufficient to generate a panel that is a good representation of the actual data.[21] To briefly explain the procedure, for every period (after the step 2 above), we count the number of individuals for each age cohort and calculate the average income across all individuals. We then simulate the economy until the distribution of individuals across age cohorts and the average income are not changing over time. In this way, the stationary distribution is achieved in 55 periods. This additional exercise supports the idea that the panel we obtained has an unbiased representation of population.

A2. Computational details

Computation of Stationary Equilibria

State space, choice variable, and timing of event. A household's current state is determined by four individual vectors, savings s, the housing asset h_{-1}, the realization of income shock z, and age a. The choice variables include savings s', housing asset h, housing ser-

[21] We run this simulation using the 5 year estimates, but the estimates from any model periods to verify this.

vices $\tilde{h}$, and non-durable consumption c. The risk-free asset is discretized into 60 spaces. Households are allowed to choose the maximum possible borrowing for each housing size, $s = (1-\theta)ph$. We define this as knots. Between each pair of knots, we allow for three equally spaced grids so that it gives more flexibility in choosing the size of mortgages. The saving grid is more finely spaced for lower levels of borrowings. For positive s, we use the increment of \$10,000 for savings up to \$200,000, and \$50,000 up to the maximum value which is capped at \$1,000,000. Houses are available in $K = 9$ discrete sizes, $h \in \{0, h(1), ..., h(9)\}$. Increasing the number for K increases the computational speed exponentially. The smallest housing size, $h(1)$ is set at 80 percent of the median income corresponding to the actual value of $\$278,700$. So in the baseline, the value of smallest house is \$328,866. We cap the largest housing size at the actual value of \$1,500,000. Houses available to renters can be smaller than the minimum housing size, we include three extra housing sizes for rent below $h(1)$ such that $h^{\text{rent}} \in \{h^{\text{rent}}(1), .., h^{\text{rent}}(3), h(1), ..., h(9)\}$. This is the grid for housing services for renters. The state space for idiosycratic income shocks is discretized into five states using the method of Tauchen and Hussey (1991).

It would be useful to describe the timing of event within a period. In any period of life, households face the following events sequentially:

1. Endowments are realized
   - idiosyncratic income shocks determine labor income
   - savings from the previous period provide return. If borrowed, households need to pay mortgage interest
2. Housing and asset decisions are made
   - sell $(1-\delta)h_{-1}$ and choose h
   - altering the net level of housing stocks, i.e. $h_{-1} \neq h$ incurs transaction costs

   Housing consumption is given by

- if $h \geq \tilde{h} > 0$, the household consumes housing services from owner-occupied housing stocks
- if $\tilde{h} > h = 0$, the household consumes housing services by renting a house

If $h > \tilde{h} > 0$, then the household becomes a landlord and receive a rental yield of NRI, defined as (6).

3. Pay tax levied on taxable income, given by (7) for the baseline economy. Receive the lump-sum transfer F.

4. Choose non-durable consumption c and finalize the amount of savings and borrowings s'.

Computation of stationary equilibrium. The stationary equilibrium is computed using constant prices, rents and transfers. We start first by guessing a those three equilibrium objects. Given prices, rents and transfers, we compute the optimal policy and value functions for the last period, $A = 14$. We then solve the household problem for all other periods using backward induction. Once we obtain policy functions, we simulate forward the economy until a stationary distribution of households over the state space is achieved. In doing so, we draw 100,000 households. Each household start their life-cycle with zero savings and housing stocks. After the end of each period, households receive an age-dependent death shock in which the death rate is obtained from the Life Table (2007-08 release) published by the ABS. We assume that the death shock follows the binomial distribution. Households exit the economy with certainty after 14 periods. If a household survives, he continues to make choices, and we simulate the optimal behavior of these households forward using the policy functions. If a household dies, he is replaced by a newly born household who starts his life-cycle from the following period. The stationary distribution is obtained when the cohort distribution and the mean of savings do not change over time. Finally, we iterate the whole process until the market clearing price, rent, and the lump-sum transfer that gives the balanced budget for the government are found. We provide more details on this in the following section.

Finding market clearing prices and rents. We follow an algorithm provided in Sommer and Sullivan (2016) in finding market clearing prices and rents. In a simulated economy, there is a cross-section of $N = 100,000$ households. The market clearing condition for housing and rental markets are given by

$$\sum_{i=1}^{N} h_i(p^*, p^{r*}|z) = H$$
$$\sum_{i=1}^{N} \tilde{h}_i(p^*, p^{r*}|z) = H$$

Solving for the equilibrium of the housing and rental markets is very time consuming because it involves repeatedly solving the household dynamic programming at potential equilibrium prices and simulating data to check for market clearing until the equilibrium prices are found.

Let p_k and p_k^r be the kth guess of the market clearing house price and rent, and let $p_k^r(p_k)$ represent the rent that clears the market for housing conditional on house price p_k. Now consider the following excess demand functions

$$ED_k^h(p_k, p_k^r) = \sum_{i=1}^{N} h_i(p^*, p^{r*}|z) - H$$
$$ED_k^{\tilde{h}}(p_k, p_k^r) = \sum_{i=1}^{N} \tilde{h}_i(p^*, p^{r*}|z) - H$$

The equilibrium house price $p*$ and rent p^{r*} simultaneously clear the housing and rental market such that

$$ED_k^h(p_k, p_k^r) = 0$$
$$ED_k^{\tilde{h}}(p_k, p_k^r) = 0$$

Algorithm:

1. Make an initial guess of the market clearing house rent p_k^r.

2. Search for the rent $p_k^r(p_k)$ which gives $ED_k(p_k, p_k^r) = 0$, conditional on the fixed house price. This step requires re-solving the household problem at each trial value of $p_k^r(p_k)$, simulating data using the optimal policy functions and checking for market clearing in the simulated data.

   The bisection method is used to find the equilibrium rent.

3. Once the set of price and rent $(p_k, p_k^r(p_k))$ that clears the housing market is found, check also if this pair clears the rental market by evaluating $D_k^{\tilde{h}}(p_k, p_k^r) = 0$

   a) if $ED_k^{\tilde{h}}(p_k, p_k^r) < 0$ and $k = 1$, the initial guess p_1 is too high, so set $p_{k+1} = p_k - \varepsilon$ and go to Step 2.

   b) if $ED_k^{\tilde{h}}(p_k, p_k^r) > 0$ and $k = 1$, the initial guess p_1 is too low, so set $p_{k+1} = p_k + \varepsilon$ and go to Step 2.

   c) if $ED_k^{\tilde{h}}(p_k, p_k^r) > 0$, the equilibrium prices are found, so stop.