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Investment Housing Tax Concessions and Welfare: Evidence from Australia

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Keywords

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JEL Classification

D15, E21, R21, R38

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Investment Housing Tax Concessions and Welfare: Evidence from Australia*

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1 Introduction

Governments adopt different policies that affect the incentives of households to invest in housing. A prominent example is the treatment of investment housing in the tax system. In some countries, such as Australia and Canada, if the rental income of a property does not cover the expenses associated with managing that property, the loss can be used to reduce total taxable income from other sources, such as labour income.[1] We describe this system as one in which investment housing expenses are *fully deductible*. In contrast, in the United Kingdom, if the expenses associated with a rental property exceed the income from that property, the loss can not be used to reduce taxable income from other sources.[2] We describe this as a system in which housing investment expenses are *partially deductible*. Many countries, such as France, Germany, Japan, and the USA are intermediate cases.[3] These differences in the tax system may affect the quantity of housing investment, the use of debt, and the incentive of households to rent or own a home.

In this paper, we examine the economic effects of *full deductibility* relative to *partial deductibility* of investment housing expenses. To do so, we study the Australian housing market which has a large private rental sector dominated by household investors. Investors are allowed to deduct their net rental losses from other income sources. This tax concession is widely used; each year over 50% of investors declare a net loss on their investment housing portfolio and use this loss to claim a deduction on their taxable income. In Australia, this feature of the tax system is called *negative gearing* and we use the terms negative gearing and full deductibility interchangeably throughout the paper.

In Section 2, we outline why some level of deductibility of investment housing expenses is a natural feature of any tax system; in short, it ensures the tax system does not distort the incentives of investors to use debt relative to equity when financing housing investment. The difference between full deductibility and partial deductibility of investment housing expenses hinges on whether losses in investment housing can be deducted from other sources of income. Full deductibility effectively subsidises investment housing losses by reducing the tax liability of an investor. However, if losses are a permanent feature of an investment it is unlikely that these losses should be subsidised. On the other hand, investors may make occasional losses due to unexpected outcomes or risk. If risk in the housing market is significant and investors are risk averse and unable to insure themselves against these risks, then the government may have a role in supporting investment in the housing market. The use of full deductibility is one way to achieve this.

[1] See Grattan Institute (2016) for a cross-country comparison of the tax treatment of investment housing losses.

[2] In the United Kingdom, losses on housing investment can be used to reduce tax on future investment housing profits by carrying forward the losses.

[3] For instance, in the US households can reduce their federal income tax liability by up to $25,000 if they experience a net rental loss. This maximum deduction is reduced if households earn more than $100,000 per year and phased out completely at a household income of $150,000.

The above discussion highlights full deductibility may be justified if housing investment is risky. Unsurprisingly, we confirm that there is a significant amount of risk in the Australian housing market. Macroeconomic models associate shocks to the value of a house as a possible risk. Jeske, Krueger and Mitman (2013), Mitman (2016), and Gete and Zecchetto (2017) incorporate such shocks in the US context to study environments with mortgage defaults. In Australia, Shao, Sherris and Hanewald (2013) study the Sydney housing market and find a significant amount of volatility in annual house price growth rates. There are other potential sources of risk in the housing market. Using the ALife Database, we find significant dispersion in estimated depreciation rates for a large cross-section of taxpayers, suggesting that homeowners face additional sources of risk.

To understand the use of negative gearing and how it affects household behaviour, we document some facts related to housing investment in Australia using the Survery of Income and Housing (SIH) and the ALife Database. We confirm that a large proportion of investors are negatively geared, i.e., claim a net rental loss. These negatively geared investors typically have high levels of mortgage debt and interest expenses account for the majority of their housing related investment expenses. Conditional upon investing in the housing market, younger households and high-income households are more likely to be negatively geared.

These stylised facts lead us to build a general equilibrium life-cycle model of housing to examine the welfare implications of full relative to partial deductibility. The model is populated by overlapping generations of finitely-lived households facing age-dependent survival rates. Households derive utility from non-durable consumption and housing services which can be acquired by renting or purchasing, and may save by investing in housing and a risk-free financial asset. As in Floetotto, Kirker and Stroebel (2016) and Sommer and Sullivan (2018), households' decisions on housing purchase and housing investment endogenise demand and supply in both rental and purchase markets. Hence, both rents and house prices respond to changes in the tax system.

In the model, households face two key sources of risk in making decisions. First, households are subject to exogenous income shocks. Second, homeowners face idiosyncratic housing shocks that reflect risk associated with owning or investing in a home. Households do not have access to insurance markets, so these risks are unable to be insured and imply that government tax policy can alter welfare by indirectly providing insurance. Our model also features the presence of credit constraints: household may borrow to purchase a house up to some limit, but are otherwise unable to access credit. As in Gervais (2002), there are minimum size restrictions associated with rental and owner-occupied housing.

We calibrate the model to match a set of key moments characterising the Australian housing market and the use of negative gearing, including the home ownership and landlord rates, the proportion of negatively geared landlords, the share of interest expenses in total expenses on investment housing, among other moments. The model does not explicitly target the patterns of home ownership rates, landlord rates, loan-to-value ratios, and fraction of negatively geared landlords by age and income or wealth quintiles, but nevertheless, matches their empirical counterparts well. The model therefore provides a reasonable environment to study changes to full deductibility of investment housing expenses.

We conduct a set of counterfactual experiments in which full deductibility is removed and replaced with partial deductibility of investment expenses. This policy change allows the government to raise additional tax revenue and our analysis focuses upon three methods of redistribution: 1) a lump-sum transfer to all households; 2) a lump-sum transfer to renters, which we interpret as rental assistance; and 3) a reduction in income taxes. When examining across steady states, the removal of negative gearing substantially reduces the landlord rate, the average debt-to-income ratio, and the fraction of negatively geared landlords in all experiments. The decline in negatively geared landlords is most significant among younger landlords and landlords with higher income. The policy reform increases the rental price and lowers the purchase price of housing; the increase in rent is larger in the rental assistance case while the drop in the purchase price is larger in the other two cases. The home ownership rate increases by 2-3 percentage points in the lump-sum transfer and income tax cases, but slightly decreases in the rental assistance case.

We use our model to examine the welfare effects of removing negative gearing. For a steady state comparison, we focus upon newborns and measure welfare using a consumption equivalent variation approach. We find significant welfare gains, equivalent to an increase in lifetime consumption of 1.5%, if the revenue from removing negative gearing is used to fund rental assistance. There are only small welfare gains, equivalent to an increase in lifetime consumption of 0.1%, if additional welfare is used to fund a lump-sum transfer, and welfare losses if income taxes are reduced proportionally. These welfare changes can be decomposed into a direct effect that reflects the change in tax policy, with prices fixed and a general equilibrium effect that reflects changes in prices, while holding tax policy fixed. Focusing upon the experiments with positive welfare gains, we find that newborns typically gain from the direct effect but are hurt by the general equilibrium effect.

To understand these welfare effects, we examine two key distortions. First, our model features missing insurance markets. Tax policies can alleviate the impact of these missing markets by implicitly providing some degree of social insurance. To study this point, we calculate the insurance premia using a *cev* measure for different policy regimes. These premia reveal how much households would be willing to pay to eliminate either housing or income risk under different tax systems. Comparing across systems, we find newborns are least willing to pay for insurance against housing risk in our baseline model with full deductibility. This supports our narrative that the presence of full deductibility is a means for the government to provide implicit support to homeowners against risky housing outcomes. This implicit insurance reduces the willingness of households to pay for private insurance against housing risk and reduces the welfare cost of missing housing insurance markets.

If full deductibility reduces the welfare cost of missing markets, why does steady state welfare increase when it is removed in our rental assistance experiment? Part of the answer is that rental assistance provides implicit insurance against *income* risk and this insurance is quantitatively more valuable than the insurance provided by full deductibility. When we evaluate the insurance premia for income risk, we find that households value income insurance the least when the tax system provides rental assistance. Renters, in our model, are either younger households or older households who have experienced negative income shocks and are unable to purchase a home. Rental assistance provides payments to these households and is an effective mechanism for the government to provide implicit income insurance. This implicit income insurance reduces the willingness to pay for income insurance and reduces the welfare cost of missing income insurance markets.

A second key distortion is the presence of credit constraints which prevent households from smoothing consumption over time. In a life-cycle model, this consumption smoothing motive is captured in a standard consumption Euler equation. In our economy, this standard Euler equation does not hold with equality due to the presence of credit constraints and other frictions. This suggests that consumption is misallocated over time. When studying the size of this distortion for renters under different policy regimes, we find that this intertemporal misallocation is smallest in the case of rental assistance and remains large when additional revenue is redistributed either in the form of a lump-sum transfer or a reduction in income taxes.

For a more complete picture of the welfare effects, we study the transition dynamics when negative gearing is removed. That is, we solve for the evolution of variables over time in response to the unexpected and permanent removal of negative gearing and evaluate the welfare of households over the transition. In both the lump-sum transfer and rental assistance experiments, households alive when the policy reform takes place experience a small welfare gain on average and about 70% of them benefit from the policy reform. A majority of renters suffer a small welfare loss in the lump-sum transfer experiment, driven by the overshooting of rent upon the removal of negative gearing. In contrast, all renters (especially poor renters) enjoy a large welfare gain in the rental assistance case. Young landlords and landlords with higher income, who are more likely to use negative gearing, benefit the least in both cases.

Following Auerbach and Kotlikoff (1987) and Kindermann and Krueger (forthcoming), we calculate an aggregate measure of welfare that considers the welfare effects on existing households and future generations that enter the economy after the policy reform is enacted. We find a small aggregate welfare gain of 0.2% in the lump-sum transfer experiment and a much larger welfare gain of 2.6% in the rental assistance experiment. This result suggests that the large welfare gain in the rental assistance case is not simply due to the redistribution between different generations. Rather, the source of welfare gain lies in a more efficient allocation of resources.

Related literature. Our paper contributes to a literature that studies the role of taxation on housing market outcomes. Gervais (2002) and Cho and Francis (2011) use a life-cycle model to study how particular features of the US tax system (mortgage interest deductibility and the non-taxation of imputed rents) affect economic outcomes. Chambers, Garriga and Schlagenhauf (2009), Floetotto et al. (2016), and Sommer and Sullivan (2018) address similar questions in a general equilibrium framework with endogenous prices. Other papers such as Karlman, Kinnerud and Kragh-Sørensen (2021) focus upon the transition dynamics associated with removing the deductibility of mortgage interest payments. Negative gearing and mortgage interest deductibility share similar features in that interest payments reduce taxable income. They differ in that negative gearing is targeted at landlords while mortgage interest deductibility is targeted at owner-occupiers. Hence, these policies will provide benefits to different segments of the population and alter the composition between rental and owner-occupied housing in different directions. Furthermore, by increasing investment housing, a policy like negative gearing may also indirectly benefit renters via general equilibrium effects. Other tax policies are studied in OLG settings by İmrohoroğlu, Matoba and Tüzel (2018) and Kaas, Kocharkov, Preugschat and Siassi (2020).

We also contribute to a literature that discusses the role of risk in housing markets. Campbell and Cocco (2015) and Corbae and Quintin (2015), among others, have focused upon the role of risk in driving the default decisions of owner-occupiers. A set of paper study how risk in the owner-occupied housing market can affect household decision making; Cocco (2004) and Amior and Halket (2014) are examples. We differ from these papers by focusing upon the effect of risk on housing investment decisions and how tax policy interacts with this risk in determining economic outcomes.

Finally, in our model rental supply is provided by household investors. Alternative frameworks, such as Graham (2021) and Garriga, Gete and Tsouderou (2020), discuss the role of large housing investors. These frameworks are inappropriate for an Australian environment where institutional investors play a very limited role.

The rest of this paper is organized as follows: Section 2 presents a simple model of how the tax system affects behaviour in the housing market. Sections 3 discusses some facts about the Australian housing market and the use of negative gearing. Section 4 describes the model. Section 5 describes the calibration strategy and compares the quantitative properties of the model with data. Section 6 discusses the quantitative results from counterfactual policy experiments, including the price and quantity effects of removing negative gearing and its impacts on aggregate and distributional welfare. Section 7 concludes.

2 The Simple Economics of Housing Tax Policy

Here, we highlight how key features of the Australian tax system affect housing investment in a simple static model. Some degree of deductibility of investment housing expenses is a natural feature of a tax system that does not distort the incentives of housing investors to use debt relative to equity finance.[4] We also highlight how full deductibility may be an appropriate policy response to the presence of risk in housing investment. We conclude this section by discussing how the treatment of capital gains alters the incentive to invest and how the lack of mortage interest deductibility for owner-occupiers encourages owner-occupied households to build up equity in their homes.

2.1 Taxes and financing investment

To illustrate how the tax system affects behaviour, we consider a simple one-period model in which an investor has a labour income of y. They can purchase a house at a price of p at the beginning of the period. They can invest in an alternative asset that provides a rate of return equal to r_a and can borrow to finance their housing investment at an interest rate of r_b. The rental income less expenses other than interest payments is R. For the moment, we abstract from the possibility of capital gains from the sale of property. Finally, suppose that the investor has enough funds to purchase the house outright. This implies that they must decide on how to finance a house purchase. We will assume that a fraction η of the house is financed using debt and a fraction $1-\eta$ is financed using equity. If they finance a house using a fraction η of debt, they will be able to invest ηp in an alternative asset that offers a return of r_a.

How does the payoff to the housing investor vary with the method of finance? In the absence of taxes, the payoff is

$$y + R + \eta p r_a - \eta p r_b.$$

Investors prefer to finance using debt if $r_b < r_a$ or prefer equity if $r_b > r_a$. Their payoff is independent of financing method if $r_b = r_a$.

A tax system may distort the incentives associated with debt relative to equity financing. Suppose interest expenses are not deductible from taxable income and income is taxed at a rate of τ. The payoff for our housing investor is:

$$(1-\tau)(y + R + \eta p r_a) - \eta p r_b$$

and the investor will maximise income by using debt to finance their housing investment if $r_b < (1-\tau) r_a$. This distorts the financing decision relative to a world in which taxes are absent. This distortion can be eliminated by allowing the deductibility of interest expenses from taxable income. In which case, the payoff to our investor would be:

$$(1-\tau)(y + R + \eta p r_a - \eta p r_b)$$

[4]This point was made previously, by Fane and Richardson (2005), among others.

and hence, the financing decision is not distorted by taxes. This system features *full deductibility* of interest expenses and is the system that currently operates in Australia.

In some countries, such as the United Kingdom, households can only deduct rental expenses from rental income. In this setting, the after-tax payment that a household would receive would be

$$\pi = \begin{cases} (1-\tau)(y + \eta pr_a + R - \eta pr_b) & \text{if } R - \eta pr_b > 0 \\ (1-\tau)(y + \eta pr_a) + (R - \eta pr_b) & \text{if } R - \eta pr_b \leq 0 \end{cases}$$

So households are taxed on their labour and asset income and can deduct interest expenses as long as the value of housing investment expenses do not exceed the value of rental income. This system features *partial deductibility* of interest expenses.

If the income from housing investment always exceed costs, these two methods are equivalent. However, if, at times, the income from a project does not meet the expenses, then investors prefer full relative to partial deductibility. It's clear that in a deterministic world that households should not invest in houses if rental income is unable to cover the related expenses. Likewise, in such a world, governments should not subsidise the purchase of investment houses by allowing losses on these houses to reduce the tax liability on other income. The situation may differ if investors are risk averse and face uncertainty in rental income. In that case, uncertainty in rental returns may discourage investment by risk averse households even if housing investment is profitable on average.[5] It also follows that in the presence of risk aversion and uncertainty, full deductibility of interest expenses could encourage socially desirable investment in housing that would otherwise not take place under a system with partial deductibility. Thus, the degree of risk associated with investment housing plays a role in determining whether full is preferred to partial deductibility. In Section 3, we will return to this point and quantify two sources of housing risk.

2.2 Other features of the tax system

Here we discuss additional features of the tax system and how they affect household behaviour in Australia. In this discussion we focus upon the treatment of capital gains and the lack of mortgage interest deductibility for owner-occupiers in Australia.

In Australia capital gains are taxed when a property is sold. If an individual has held the property for longer than one year there is a 50% discount in calculating the size of the capital gain for tax purposes. This discount is a simple method to account for the desire to tax real rather than nominal profits. To see this point, imagine if the price of an investment house increased at the rate of inflation. Then the real value of the house would be unchanged. However, when sold, an increase in the nominal value of the house would

[5]See Appendix B.1 for a more formal discussion on this point.

generate a nominal capital gain and a tax liability on the capital gain would lower the real return on investment and discourage investment in the housing market.[6] Intuitively, the capital gains discount will encourage investment in housing relative to a setting without it. A formal discussion of this effect in our simple model is in Appendix B.2.

A second feature in the Australian tax system is that interest payments associated with mortgages on owner-occupied housing are not deductible from taxable income. To see how this affects household behaviour, consider the following example: a household has enough funds to purchase a home outright. Again, assume that they are able to use debt to cover a fraction η of their purchase. In this case, the after-tax income to a homeowner is,

$$(1-\tau)(y+\eta p r_a) - \eta p r_b$$

where $R = 0$ since we focus on owner-occupied homeowners. The absence of mortgage interest deductibility means that homeowners have an incentive to pay down debt (that is, set $\eta = 0$) to maximise after-tax income if relative interest rates are such that $r_b > (1-\tau)r_a$. Of course, housing investors often live in a home they own. If the interest rate on debt is such that $r_b \in [(1-\tau)r_a, r_a]$, then a housing investor would have an incentive to maintain debt in investment housing while repaying debt associated with owner-occupied housing as rapidly as possible. In Section 3, we will see that this is indeed how households behave.

3 Data

This section presents some important facts on the Australian housing market, with a focus upon how the tax policies discussed in Section 2 are reflected in the data. We use these facts in constructing and calibrating our model. We utilise two datasets extensively. First, the 2013-14 Survey of Income and Housing (hereafter, SIH) provided by the Australian Bureau of Statistics (ABS). This is cross-sectional survey data that record household income, wealth, and other variables. Using this dataset we are able to study the balance sheet characteristics of households but it has limited information on income and expenses of housing investors. We also use the ALife Database provided by the Australian Tax Office (ATO). The ALife Database contains adminstrative data on the tax returns for 10% of Australian taxpayers and follows these taxpayers over time. ALife does not contain balance sheet information, but does contain detailed information on the income and expenses of housing investors. Appendix A provides more details on these datasets.

We begin by describing the distribution of housing tenure using data from the SIH. In Australia, 33.5% of households own their home outright and an additional 35.0% are in the process of purchasing their home. The remaining 31.5% of households participate in

[6] The low rate of inflation in recent decades has led some to argue (Grattan Institute, 2016) that the capital gains discount has been excessively generous and encouraged excessive housing investment .

Table 1: Annual rental income and expenses of investors by gearing status

	All investors	Negatively geared investors
Rental income	$19,102	$16,412
Total expenses, of which:	$20,967	$26,209
- Interest expenses	$10,559	$14,206
- Capital works expenses	$1,354	$1,703
- Other rental expenses	$9,054	$9,300

Source: ALife Database 2013-14.

the rental market. The majority of renters are engaged in the private rental market due to a limited supply of public housing. At the same time, from the SIH we find that 13% of households are landlords. The majority of these (72%) only own a single investment property. Less than 10% of households own more than two rental properties.

The role of institutional investors in the Australian housing market is limited as the tax system discourages large investors. This is discussed in detail by Henry, Piggott, Ridout and Smith (2009).[7] In short, generous tax-free thresholds are applied to land tax: investors with small land holdings are often tax exempt while large investors are subject to large annual taxes. Despite that, there are still some large housing investors: the ALife Database suggests that the top 1% of rental investors earned 9.5% of total rental income.

3.1 Negative gearing and debt

We use the ALife Database to study the behaviour of housing investors. Housing investors are defined as individuals that report a rental housing income that exceeds the value of $3,120 over the financial year.[8] In the 2013-14 financial year, we find that 59.4% of investors were negatively geared with expenses exceeding rental income.

In the ALife Database, investment housing expenses are grouped into three categories: i) interest expenses, ii) capital works, and iii) other rental deductions. The average levels of expenses by category for all investors and negatively geared investors are displayed in Table 1. Examining these categories we find that interest payments account for 50% of all expenses associated with investment properties and an even higher percentage of expenses (54%) among negatively geared investors. This suggests that negatively geared households maintain higher levels of debt and as a result, have higher interest expenses associated with their investment property than non-negatively geared investors.

[7] See page 261-2.

[8] We restrict attention to individuals with rental income greater than $3,120 for the following reason: the SIH reveals that the rent paid by the lowest percentile in the rental distribution is $6,240. We remove housing investors with rental income less than half of this value on the basis that these investors are unlikely to be genuinely providing long-term rental housing. About 9% of households with rental income earn below this threshold.

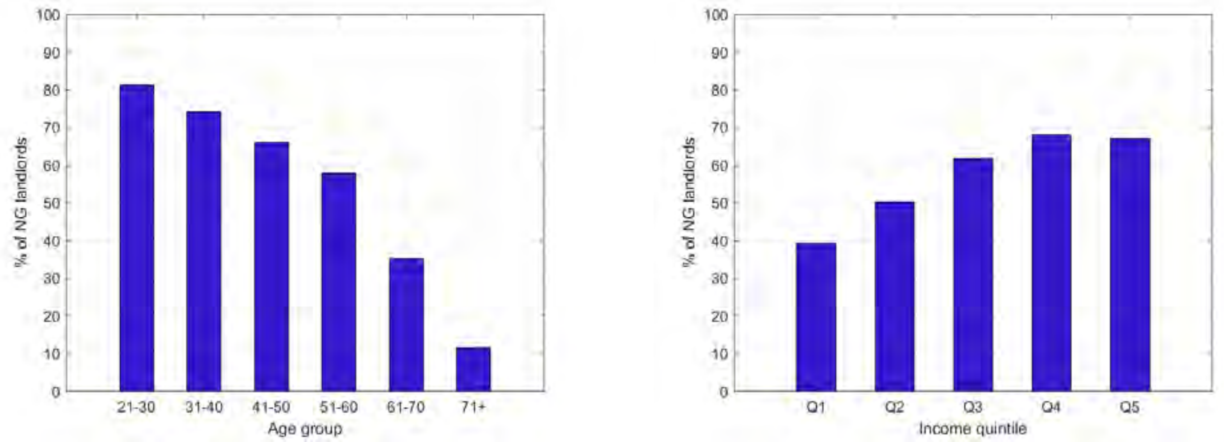


Figure 1: Proportion of negatively geared landlords by age and income quintile

Source: ALife Database 2013-14.

When studying investors in more detail, we note that negatively geared investors are younger than positively geared investors and despite being younger tend to have higher taxable incomes, on average. This is reflected in Figure 1 which shows that conditional upon being a landlord, young and high-income households are more likely to be negatively geared. Younger households have more time to repay debt and can access larger mortgages. Higher income households are, other things equal, able to access larger mortgages as well. Larger mortgages are associated with greater interest payments. Higher income households are also subject to higher marginal tax rates. As highlighted in Section 2, negative gearing provides a subsidy when a housing investor makes a loss and the size of the subsidy is larger, the higher is the marginal rate of tax. Hence, it is not surprising that higher income households are more likely to be negatively geared.

As mentioned in Section 2, the presence of negative gearing does not distort the incentive of an investor to use a particular method of finance. However, the tax system does create clear differences in behaviour between investors and owner-occupiers. Figure 2 displays the percentage (by value) of interest-only loans out of total loans for owner-occupier and for investment mortgages. Over 60% of investment loans by value are interest-only. This allows investors to retain high debt levels, raise their leverage and increase the rate of return from profitable investments. In contrast, only around 20% of loans by value to owner-occupiers are interest-only. As discussed in Section 2, interest expenses can not be deducted from taxable income by owner-occupiers. Households that live in their own home and have an investment home, have an incentive to maintain high debt in investment housing, which is tax deductible, and minimise debt in owner-occupied housing, which is not tax deductible. As a consequence, the use of interest-only loans is much more prevalent for investment than for owner-occupied loans. The use of interest-only loans is a mechanism via which investors are able to delay the repayment of debt on investment mortgages.

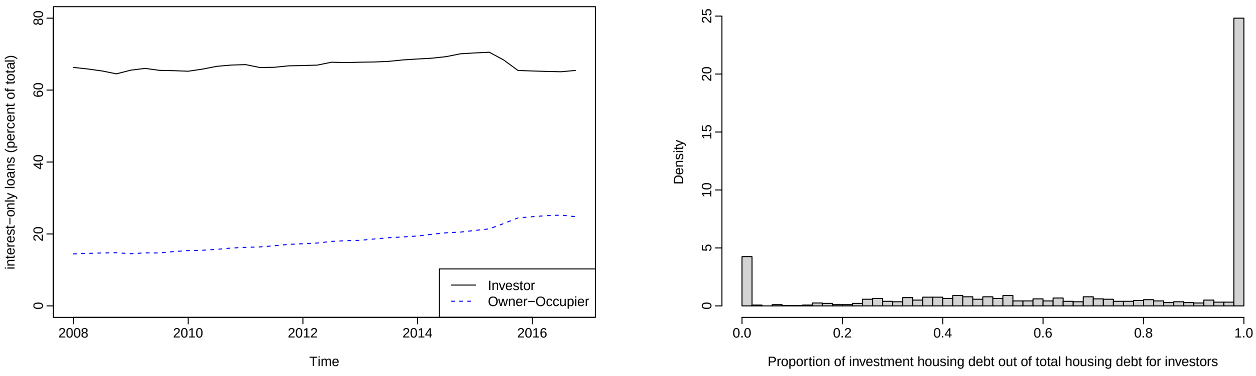


Figure 2: Interest-only loans as a proportion of total debt by type of mortgage (left); histogram of the ratio of investment housing debt to total housing debt for investors (right)

Source: Reserve Bank of Australia (left panel); SIH 2013-14 (right panel).

We use the SIH to examine how debt by housing investors is allocated between owner-occupied and investment mortgage loans. Examining the data, we find that 21.7% of housing investors do not have any housing debt. A further 37.5 percent of housing investors only have investment housing debt and do not have any owner-occupied housing debt. 34.1% of households have both investment and owner-occupied debt while the remaining 6.5% have only owner-occupied debt and no investment housing debt. In the right panel of Figure 2, we show a histogram of the distribution of the ratio of investment housing debt to total housing debt for housing investors with positive debt values. A value of one indicates that a household only has investment mortgage debt while a value of zero indicates that a household only has owner-occupied mortgage debt. Overall, a significant portion of housing investors allocate debt towards investment housing debt and away from owner-occupied housing debt. We also note that economic theory has difficulty in explaining the 6.5% of housing investors that have owner-occupied debt without investment housing debt.[9]

3.2 Risk in housing assets

In previous work, a series of papers have related risk in housing to fluctuations in the price of a house.[10] These papers often focus upon price volatility as a source of risk for homeowners and appeal to data gathered in the USA by the Federal Housing Finance Agency (FHFA).[11] In Australia, Shao, Sherris and Hanewald (2013) study house price indices with a focus

[9]A small portion (about 10%) of investors with only owner-occupied debt have incomes below the tax-free threshold. In this case the allocation between owner-occupied and investment housing debt does not affect payoffs. For the remaining households, refinancing to shift debt from owner-occupied to investment mortgages would raise after-tax income. Potentially these investors may be discouraged by refinancing costs or by behavioural factors.

[10]See for example, Jeske et al. (2013), Mitman (2016), and Gete and Zecchetto (2017).

[11]The FHFA was formed by combining the Federal Housing Finance Board and the Office of Federal Housing Enterprise Oversight (OFHEO). The OFHEO constructed house price indices prior to the FHFA.

upon the Sydney housing market. They use a variety of methods to construct house price indices and for each method calculate the implied standard deviation of annual house price growth over the period from 1971-2011. The mean value of the implied standard deviations of annual house price growth rates from these different methods is 0.042. This quantifies one potential source of risk in housing investment.

It is also possible that housing risk arises due to unexpected maintenance expenses on a house. We describe these shocks as depreciation shocks. We use the ALife Database to examine this possibility. The ALife Database has detailed information on rental income and expenses but, unfortunately, lacks data on the value of housing. To infer the degree of depreciation risk associated with housing, we use rental income and an average rental rate of return to impute the value of rental property for each investor in the ALife Database. In particular, we estimate the value of a rental property owned by investor i to be equal to

$$\hat{p}_i = \frac{\text{rental income}_i}{\text{rental rate of return}}.$$

In this calculation, we use a rental rate of return equal to 4.8 percent per annum which implies a median house value close to that observed in the SIH. With this imputed house value, we then calculate an estimated depreciation rate for each investor in the ALife Database:

$$\hat{\delta}_i = \frac{\text{depreciation}_i}{\hat{p}_i}$$

where the value of depreciation is the combination of *capital works expenses* and *other rental expenses*. Capital works expenses include depreciation of existing structures. Other rental deductions are a mix of both depreciation for smaller items such as carpets, fixtures and fittings, and other expenses such as real estate agent and council fees. Unfortunately, we are unable to separate the component of other rental deductions into a component related to depreciation and a separate component.

Examining the distribution of $\hat{\delta}_i$, we find a mean value of 0.028 and a standard deviation of 0.018 which implies a significant amount of dispersion in estimated depreciation rate. The presence of house price volatility and depreciation risk motivate the introduction of an exogenous shock to house values in our economic model to be described below.

We summarise our findings as follows. A large proportion of investors in the Australian housing market are negatively geared, driven by maintaining high levels of debt in their investment properties. This results in large interest expenses that are deductible from other sources of income. It is well accepted that homeowners are subject to a range of risks in the housing market (see Campbell and Cocco (2015) for example). We document that homeowners are subject to risk in the form of unexpected housing price changes and risk in depreciation rates.

4 Model

To analyse the effects of negative gearing, we develop a general equilibrium OLG model with heterogeneous agents and incomplete markets. The economy is populated by overlapping generations of households who are subject to idiosyncratic income shocks and shocks to the house value. Household utility depends upon a non-durable consumption good and housing services. Housing services may be rented or purchased. Homeowners can lease out part of their existing housing stock to other households and become a landlord. The decision to become a landlord is affected by government tax policy. The purchase and sale of houses incur transaction costs and homeowners must pay maintenance costs to prevent housing from depreciating. In every period, the equilibrium price and rent are determined by the appropriate market clearing conditions. A competitive construction sector adjusts the supply of new housing stock in response to price changes.

4.1 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 one-period survival rate of κ_a, and they die with certainty after period A.[12] To maintain a constant population, households that exit the economy are replaced by new-born households. These newborns enter the economy with zero wealth but may have different income levels.

Preferences. The utility function of a household is given by:

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

where c represents non-durable consumption and $\tilde{h}$ represents the consumption of housing services. In a frictionless environment, α would correspond to the share of expenditure devoted to non-durable consumption and σ is the standard coefficient of relative risk aversion. Following Chu (2014), λ is a parameter that allows for a preference to own rather than rent. In particular, $\lambda = 1$ if a household is a renter and $\lambda > 1$ if they own a house.

As in De Nardi (2004) and Cocco (2004) households receive utility from providing a bequest given by

$$\nu(\mathrm{b}) = \vartheta\frac{\mathrm{b}^{1-\sigma}}{1-\sigma}, \tag{2}$$

where ϑ determines the importance of bequest utility. The size of a bequest, b, equals the

[12] The use of negative gearing varies with age (as discussed in Section 3). As a result, matching both individual and aggregate behaviour requires an accurate age distribution. Having age-dependent survival rates help us achieve that.

assets of a deceased household. This bequest motive helps the model to match wealth accumulation and home ownership rates for the old. We assume that bequests are collected by the government to fund government consumption which does not enter into the household utility function.[13] Households maximize the present value of expected discounted lifetime utility with $\beta \in (0, 1)$ being the relevant discount factor.

Endowment. Labour income is composed of a deterministic and a stochastic component. The deterministic component is a function of age and is denoted, η_a, and is common to all households. The stochastic component varies with household i and is denoted $z_{i,a}$. We assume that the labour income received by household, i, at age, a, is

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

and $z_{i,a}$ follows the law of motion:

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

In our computation the stochastic process for $z_{i,a}$ is approximated by a Markov chain with income states $z \in Z \equiv \{z_1, \ldots, z_J\}$. The stochastic income shock is a key source of heterogeneity. It generates dispersion in economic resources within and across age groups. This dispersion helps generate differential consumption, savings, and housing choices across households.

Housing. Housing services $\tilde{h}$ can be obtained by purchasing or renting. A household that has purchased a quantity of $h_{-1} > 0$ units of housing at the end of previous period can consume $\tilde{h} \leq h_{-1}$ in current period. If $h_{-1} = 0$, the household is a renter and must rent housing services in current period at the rental price p^r per unit of housing. If $h_{-1} > 0$, the household is a homeowner and can consume less housing services than they own ($\tilde{h} < h_{-1}$), in which case they become a landlord with an investment housing stock of $h_{-1} - \tilde{h}$. Households choose to purchase housing stock h for next period at the purchase price p per unit of housing. Note that we assume the housing stock that provides housing services and possibly rental income in current period is acquired at the end of previous period, before idiosyncratic uncertainties for current period are realised. Also, only homeowners can become landlords, i.e., there are no renter-landlords.[14]

[13]This assumption is also made by Floetotto et al. (2016). Bequests could be distributed to newborn (or other) households. We do not follow this route as it would mean that the bequests would increase the utility of households as they die and also increase the lifetime utility of newborns indirectly by increasing their assets and hence future consumption. This generates a source of double-counting, so to speak, in that policies that encourage larger bequests will tend to increase welfare other things equal.

[14]Both HILDA and the SIH report that approximately 3% of the sampled households are renters who are also landlords.

Housing risk. Section 2 highlights that the degree of risk associated with housing may affect the desirability of negative gearing. In particular, if housing is risky enough, risk averse homeowners may be discouraged from housing investment. Section 3 discusses volatility in prices and depreciation as two potential sources of risk in the housing market. To incorporate risk into our model we include a shock to home values in the spirit of Jeske et al. (2013) and Gete and Zecchetto (2017). This shock captures both randomness in the maintenance costs *and* potential changes in the value of the house. The change in house value could be due to changes in the quality of the neighbourhood or other amenities associated with the house. Formally, homeowners face an idiosyncratic stochastic depreciation rate $\delta_\omega = \bar{\delta} + \omega$, where the parameter $\bar{\delta}$ is the mean depreciation rate and ω is a mean zero shock drawn from a continuous distribution with standard deviation σ_ω. The realisations of ω are independent over time and across households.[15] In the computation, the distribution is approximated with a discrete distribution with finite state space $\Omega \equiv \{\omega_1, \ldots, \omega_M\}$. A house of value ph_{-1} acquired at the end of $t-1$ has a value of $(1-\delta_\omega)ph_{-1}$ at time t if the realised shock in t is ω. We allow δ_ω to take negative values in some states of ω, in which case the shock leads to a capital gain for the household.

With this structure households, on average, must set aside $\bar{\delta}ph_{-1}$ to cover depreciation. In some periods, depreciation is higher than average and in other periods, the household may enjoy an appreciation. This feature allows households to benefit from a capital gain despite zero expected capital gains ex-ante.[16]

Transaction costs. Housing transactions are subject to costs that generate inaction regions in the households' decisions to buy or sell. We assume the transaction cost of buying (selling) a house is a constant fraction ϕ^b (ϕ^s) of the market value of the house. The total transaction costs of changing from h_{-1} to h, denoted by $TC(h_{-1}, h)$, is

$$TC(h_{-1}, h) = \begin{cases} 0 & \text{if } \; h_{-1} = h \\ \phi^b ph + \phi^s ph_{-1} & \text{if } \; h_{-1} \neq h \end{cases} \tag{5}$$

These transaction costs are a dead-weight loss. Finally, ζ is a fixed, per period cost for landlords associated with maintaining a rental property.

Financial assets. Households can accumulate wealth by purchasing housing and by accumulating a risk-free financial asset. A household enters current period with financial assets

[15] Genesove and Hansen (2020) study house price dynamics using matched housing sales in Sydney and Melbourne. They find changes in house prices indices of houses sold at auction exhibit low persistence.

[16] Jeske et al. (2013) and Gete and Zecchetto (2017) introduce a similar shock to allow for mortgage default. In our setting, mortgage default is not allowed. This is reasonable since in Australia, default rates are low and the share of non-performing mortgage loans in Australia has remained below 1%. For details, see Read, Stewart and La Cava (2014). This low default rate could reflect that mortgage loans are recourse loans.

acquired in previous period s_{-1}. If the household has savings, i.e. $s_{-1} > 0$, the asset pays an interest rate r. If the household has borrowed, i.e. $s_{-1} < 0$, the interest rate on debt is $r + m$ where $m > 0$ represents the premium associated with borrowing. Australia is treated as a small open economy, so we assume both r and m are determined exogenously. The household chooses new holdings of financial assets s for next period.

Homeowners can use their house as collateral for borrowing, subject to the following borrowing constraint:

$$s \geq -(1-\theta)ph, \tag{6}$$

where $\theta \in [0, 1]$ is the minimum percentage downpayment to purchase a house. This constraint captures the loan-to-value (LTV) limit imposed when households take out a mortgage. Borrowers also face a debt-to-income constraint:

$$s \geq -\gamma Y, \tag{7}$$

where Y is a household's total taxable income (to be described below) and $\gamma > 0$ is the exogenous maximum debt-to-income (DTI) ratio.

Taxation. Households pay tax on labour income, income from financial assets, and net rental income (NRI) (if they are landlords) which is defined as

$$\begin{aligned} NRI \equiv & \left[p^r - p\delta_\omega \left(1 - \frac{\mathbb{1}_{\{\delta_\omega < 0\}}}{2}\right)\right](h_{-1} - \tilde{h}) \\ & -(r+m)\min\left\{-s_{-1}, \varphi p(h_{-1} - \tilde{h})\right\}\mathbb{1}_{\{s_{-1}<0\}} - \zeta, \end{aligned} \tag{8}$$

where $\mathbb{1}$ is an indicator function which takes a value of 1 if its argument is true and a value of zero otherwise. The NRI consists of three components. First, there is the rental income earned net of depreciation or maintenance costs. As discussed in Section 2, landlords have access to negative gearing and a capital gains tax discount of 50%. We incorporate these tax rules for investment housing in the definition of NRI; a landlord can fully deduct the depreciation cost (when $\delta_\omega > 0$), but only 50% of the capital gains on their investment housing stock (when $\delta_\omega < 0$) are taxable.[17] The second component reflects the interest expenses on mortgages associated with investment housing. In reality, as illustrated in Figure 2, landlords have the incentive to accumulate investment mortgage debt while minimizing owner-occupied mortgage debt. To capture this, we introduce a parameter φ to indicate the maximum LTV ratio for investment housing such that a landlord can claim their interest expenses on investment housing loan $\varphi p(h_{-1} - \tilde{h})$ or total debt $-s_{-1}$, whichever is smaller.

[17] We simplify the treatment of capital gains to maintain a feasible state vector. In reality, a capital gain is realised when a house is sold. In our model, a capital gain is realised in the period in which a negative house value shock is drawn. To coincide with reality, we would need an additional state variable to record unrealised capital gains.

The final term is the per period fixed cost associated with being a landlord.

We see from (8) that high interest expenses on mortgages and a large depreciation cost relative to rental income can lead to negative net rental income and make the landlord negatively geared. The total taxable income of a household is given by:

$$Y = y_a(z) + rs_{-1}\mathbb{1}_{\{s_{-1}>0\}} + NRI\,\mathbb{1}_{\{h_{-1}>\tilde{h}\}}, \tag{9}$$

where $y_a(z)$ is used to denote the household's income which depends on their age a and idiosyncratic income shock realization z. If the household is making a loss from housing investment, i.e. $NRI < 0$, full deductibility applies and reduces their taxable income. The total tax payment is represented by $T(Y)$.

In Section 6, we run counterfactual policy experiments by replacing full deductibility with partial deductibility, i.e., setting the taxable income as below:

$$Y = y_a(z) + rs_{-1}\mathbb{1}_{\{s_{-1}>0\}} + NRI\,\mathbb{1}_{\{h_{-1}>\tilde{h} \text{ and } NRI>0\}}. \tag{10}$$

In this case, households cannot reduce the taxable labour or asset income when a net rental loss is realised. This is similar to the tax treatment in the UK.

We now express the budget constraint for a household in an arbitrary period as:

$$\begin{aligned} c + \delta_\omega\, ph_{-1} + p^r\tilde{h}\mathbb{1}_{\{h_{-1}=0\}} + \zeta\mathbb{1}_{\{h_{-1}>\tilde{h}\}} + T(Y) + s + ph + TC(h_{-1}, h) \\ = y_a(z) + p^r \max(h_{-1} - \tilde{h}, 0) + (1 + r + m\mathbb{1}_{\{s_{-1}<0\}})s_{-1} + ph_{-1}. \end{aligned} \tag{11}$$

The left hand side of (11) is the total expenditure of the household, including expenditure on non-durable consumption, maintenance cost on existing housing asset, rental cost if a renter, fixed cost if a landlord, tax payment as a function of taxable income, savings or borrowings for next period, and purchase cost of housing for next period together with possible transaction cost. The right side is the total income, including labour income, rental income, interest income from savings or interest expenses on debt, and income from the sale of their existing home.

Household Dynamic Programming Problem. A household of age a enters current period with financial assets s_{-1} and housing assets h_{-1} acquired at the end of previous period. If $h_{-1} = 0$, the household is a renter and must rent housing services. A renter's budget constraint and payoff is independent of ω so we let $\omega = 0$ for all renters. If $h_{-1} > 0$, they are a homeowner and can choose to become a landlord. Then the household's idiosyncratic income shock z and depreciation shock ω are realised. Given house price and rent, (p, p^r), the household chooses non-durable consumption c and housing services $\tilde{h}$ for current period, and also decides upon housing stock h and financial asset s for next period. A timeline describing the order of events is presented in Figure 3.

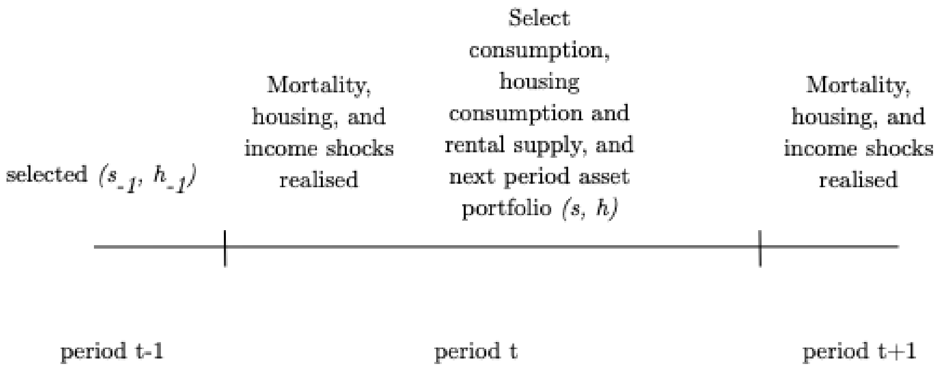


Figure 3: Timeline of household decision making

We group the state variables into a state vector $x \equiv (a, z, \omega, s_{-1}, h_{-1})$. The dynamic programming problem of the household can be formulated as follows:

$$V(x) = \max_{c, \tilde{h}, s, h} \left\{ u(c, \tilde{h}) + \beta \left[\kappa_a \mathbb{E}_{(z', \omega') | (z, \omega)} V(x') + (1 - \kappa_a) \nu(\mathrm{b}) \right] \right\} \tag{12}$$

subject to the budget constraint (11) and the borrowing constraints (6) and (7), where the bequest b is defined as

$$\mathrm{b} = s + p(1 - \phi^s)h,$$

and $x' \equiv (a + 1, z', \omega', s, h)$ is the state vector for next period.

4.2 Government sector

The total tax a household with taxable income Y pays is given by $T(Y)$ with details on this function to be presented below in Section 5. In our baseline economy, tax revenue is used to fund government consumption that does not enter into the household problem. This assumption reduces computational burden since the government budget constraint is not an equilibrium condition to be satisfied in the baseline model. The removal of full deductibility eliminates a source of tax deductions and, hence, raises government tax revenue. This revenue is redistributed in a revenue-neutral fashion. In our counterfactual experiments we study the welfare implications of different methods of revenue-neutral redistribution.

4.3 Construction sector

We endogenize housing supply in the following way. A foreign-owned construction firm produces housing to create new dwellings. As in Floetotto, Kirker and Stroebel (2016), the firm has access to the following production technology,

$$H^{\text{new}} = \psi_1 L^{\psi_2}$$

where H^{new} is the new housing constructed, and L is the amount of land used in the production process. The parameters ψ_1 and ψ_2 determine the scale and degree of decreasing returns in the production process, respectively. The firm maximises profits by selecting an amount of land to purchase from the government, converting this land into housing, and then selling housing at the market price, p. We assume that the supply of land is perfectly elastic and hence normalise the price of land to one. The firm maximises profit from the sale of housing using land as an input in each period:

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

which implies,

$$H^{\text{new}} \equiv p\psi_1 (L^*)^{\psi_2} = \psi_1 \left(\frac{1}{\psi_1 \psi_2 p} \right)^{\frac{\psi_2}{\psi_2 - 1}} \tag{13}$$

so that the housing supply elasticity is $\varepsilon = \psi_2/(1-\psi_2)$.

The construction firm earns positive profits. We assume these profits generate dividends that are distributed to the foreign sector. Also, any revenue from the sale of land that accrues to the government is not redistributed to households. We make these assumptions to prevent the market structure of the construction sector or a government monopoly of land from driving our quantitative results. The transition equation for the aggregate housing stock is given by

$$H = H_{-1}(1-\bar{\delta}) + H^{\text{new}}. \tag{14}$$

4.4 Equilibrium

A stationary equilibrium is obtained by first solving the household and construction firm's optimisation problems for given prices p and p^r. Aggregating households' behaviour gives aggregate demand for housing assets, as well as the demand and supply of rental housing. The equilibrium then requires to find p and p^r that clear both the housing and rental markets. Appendix B.3 provides a formal definition of the stationary equilibrium and Appendix E details the computational algorithm.

5 Calibration

We calibrate the model in two stages. In the first stage parameters are selected by appealing to evidence from micro-data and the existing literature. In the second stage, the remaining parameters are set by matching the model moments of the baseline steady state to their counterparts in micro-data as closely as possible.[18] We summarise parameters that are exter-

[18]Our income process is estimated using HILDA data over the period 2001-15. The rest of our microeconomic data are derived from the 2013-14 SIH and from the corresponding version of ALife. These data

Table 2: Externally chosen parameter values

	Parameter	Model value	Annual value	Source
r	Risk-free interest rate	0.041	0.020	RBA
m	Mortgage premium	0.046	0.023	RBA
σ	Coefficient of risk aversion	2		Literature
ϕ^b	Trans. cost for buyer	0.04		Avg. stamp duty
ϕ^s	Trans. cost for seller	0.02		Avg. agent fee
$\bar{\delta}$	Average depreciation rate	0.051	0.025	Harding et al. (2007)
θ	Downpayment requirement	0.2		
κ	Debt-to-income limit	5		
η_a	Deterministic part of income			HILDA
ρ	Persistence of income shock	0.837	0.940	HILDA
σ_u	Std. dev. of income shock	0.320	0.173	HILDA
κ_a	Survival probabilities (age-dependent)			ABS life table
$T(Y)$	Taxation thresholds and proportions	Refer to text		ATO
ε	Housing supply elasticity	2		Liu and Otto (2014)

nally determined in Table 2. The parameters calibrated internally are summarised in Table 3 while the corresponding data and model moments are reported in Table 4.

5.1 External calibration

Demographics and Preferences. Each period corresponds to 2 years. The age (in model periods) is denoted by a. Each period, the one-period survival probability of a household conditional upon living until age a is given by κ_a. These probabilities are taken from the ABS Life Tables 2014-2016.[19] We set $\kappa_{32} = 0$ implying all households surviving 32 periods exit with certainty. With this structure, households enter at age 21 and survive until a maximum age of 84.

Income. The stochastic income process is estimated using income and age data.[20] The deterministic component of income is modelled using a sixth order polynomial. The stochastic component of income follows the AR(1) process in (4). For a two-year model, we estimate $\rho = 0.837$ and $\sigma_u = 0.32$ that reflect the persistence and standard deviation of innovations. Details on estimation are in Appendix F. We follow Tauchen and Hussey (1991), and approximate the income process with seven discrete states.[21]

come from a period of significant change in the Australian housing market during which interest rates declined and purchase prices of housing have increased. However, the policy of negative gearing has remained constant throughout this period.

[19]See https://cutt.ly/9UQiCMm for details.

[20]We use HILDA data to calibrate the income process. Exogenous income in our model excludes investment income (housing and financial assets); to be consistent with the model, we take *household total gross income* and subtract investment income (rental income and savings).

[21]The median household income over a two-year period is $269,280; this value is used to normalise quantity variables in the model unless otherwise stated.

Housing. We set the transaction cost for buyers $\phi^b = 0.04$ which is the average housing transaction tax rate across the seven capital cities in Australia from 2011 to 2014. The transaction cost for sellers is $\phi^s = 0.02$ which corresponds to the average real-estate agent fee in Australia. Harding, Rosenthal and Sirmans (2007) estimate the depreciation rate on housing as 2.5% per year, so we set the mean depreciation rate over the two-year period of our model as $\bar{\delta} = 0.0506$.

We discretize the state space of housing size that households may purchase or rent. Following Gervais (2002), we introduce a minimum housing size for owner-occupiers, h_{min}. The maximum housing size is about six times larger than h_{min} and is rarely chosen in equilibrium. We then discretize this range into nine housing grids, with the first grid equal to h_{min} and the last equal to the maximum size. We allow renters to consume housing services less than the minimum housing size for owner-occupiers to reflect shared accommodation. So renters have a smaller minimum housing size, $h_{min,rent} < h_{min}$, and four additional discrete sizes for rental housing.[22] Both h_{min} and $h_{min,rent}$ are internally calibrated below.

Unfortunately, we are unaware of any estimates of housing supply elasticity for the aggregate economy. Hence, we adopt the measures of housing supply elasticity estimated by Liu and Otto (2014) who focus upon the Sydney housing market. They estimate a supply elasticity in the range of 0.07 - 0.96 for houses and 0.16 - 4.34 for apartments. We set $\varepsilon = 2$. This value is slightly above their estimate, reflecting our belief that the Sydney housing market is more constrained by geography than the rest of Australia.[23]

Interest rates. The risk-free interest rate is set to the average yield of the 10-year Commonwealth government bond from 2003 to 2013, deflated by annual CPI inflation. This implies a real interest rate of 2.02% per annum, equivalent to a model value of $r = 0.041$. The mortgage rate is obtained from the real variable lending rates for owner-occupied housing over the same period. The annual average rate is 4.25% which translates into a two-year value of $r + m = 0.087$. This gives a value of mortgage premium, $m = 0.046$.

Borrowing constraints. The parameter θ in the borrowing constraint (6) is set to 0.2, consistent with a typical downpayment requirement of 20% for residential mortgage lending in Australia. To set the DTI limit we use data from the SIH. In particular, we calculate the ratio of mortgage debt to household income for each household in the sample. The DTI ratio at the 98th percentile is marginally below 10 using annual income. As a result, we set $\gamma = 5$ (see Equation (7)).

Taxation. The income tax function captures the progressivity of the Australian tax sys-

[22]Our targeted moments are not sensitive to further increasing the fineness of the housing grid.

[23]In Appendix D.1, we provide the results for two alternative values of ε, $\varepsilon = 0$ and $\varepsilon = 4.5$, which are close to the lower and upper bounds of Liu and Otto (2014).

tem. The tax function $T(Y)$ is a step function of the taxable income, defined by the income thresholds for each tax bracket, the marginal tax rates, and the tax payment thresholds for each bracket. They are obtained from the ATO using the income tax system for the 2013-14 financial year. The tax function $T(Y)$ is then given by:

$$T(Y) = \begin{cases} 0 & \text{if } Y \leq 0.135 \\ 0.19(Y - 0.135) & \text{if } 0.135 < Y \leq 0.275 \\ 0.027 + 0.325(Y - 0.275) & \text{if } 0.275 < Y \leq 0.594 \\ 0.130 + 0.37(Y - 0.594) & \text{if } 0.594 < Y \leq 1.337 \\ 0.405 + 0.45(Y - 1.337) & \text{if } 1.337 < Y \end{cases}$$

Here we normalise the income and tax payment thresholds by the median two-year household income.

5.2 Internal calibration

After calibrating some parameters on the basis of information from micro-data and other external sources, we are left with 10 undetermined parameters. We use a simulated method of moments procedure to estimate these parameters by matching important moments observed in the data, from the SIH and ALife. These internally calibrated parameters and the target moments are reported in Tables 3 and 4 respectively.[24]

Our model is non-linear and changes in one of the exogenous parameters can alter multiple endogenous moments. To proceed with our calibration exercise we discuss each exogenous parameter that needs to be calibrated and highlight the moment that is selected to help with the calibration of this parameter.

We begin with a discussion of the underlying preference parameters of households. To estimate the utility premium for home ownership, λ, we include the home ownership rate as one of our targets. As λ increases there is a strong tendency for the home ownership rate to increase. The parameter ϑ determines the intensity of bequests in our model and changes in this parameter affect the willingness of older households to remain in owner-occupied housing; we include the home ownership rate for households over the age of 65 as a target moment.

To estimate the discount factor, β, we include the median LTV ratio as a target.[25] The value of β impacts upon a household's willingness to borrow and repay debt. As a result, changes in β have a large impact upon the median LTV ratio in the model. Our final preference parameter is α which in an economy without size and credit constraints would reflect the share of expenditure on non-durable consumption relative to total consumption. Ideally, we would calibrate this parameter by including the rent to non-durable consumption as a

[24] Details of the calibration procedure are provided in Appendix E.

[25] The LTV ratio for each household is calculated using information on the remaining mortgage balance and self-reported housing value of the household in the SIH.

Table 3: Internally calibrated parameters

	Parameter	Value
λ	Utility premium for homeowners	1.06
h_{min}	Minimum housing size for owning	0.335
$h_{min,rent}$	Minimum housing size for renting	0.142
ϑ	Bequest intensity	3.5
β	Discount factor (2-year)	0.852
α	Share of non-durable consumption	0.680
ζ	Fixed cost of being a landlord	0.048
φ	Maximum LTV ratio for investment housing	0.982
σ_ω	Size of depreciation shock	0.071
ψ_1	Scale parameter for housing production	4.712

Notes: The values for $h_{min,rent}$, h_{min} and ζ correspond to a minimum annual rental payment of \$10,286, a minimum value of \$283,147 for owner-occupied housing, and a fixed annual cost for a landlord of \$6,517.

target moment but reliable consumption data are hard to find. Instead, we select the rent-to-income ratio as an appropriate target moment and note that an increase in α tends to raise this ratio.

Our model features a number of parameters relevant to the housing market. First, ζ is the fixed cost of being a landlord and it has a large impact upon the proportion of landlords or landlord rate in the economy. We therefore include the landlord rate as a target moment. There is a minimum house size for rental accommodation, $h_{min,rent}$, and a minimum size for owner-occupied housing, h_{min}. In the SIH, we find that the rental expenditure by households at the 15th percentile of the rental expenditure distribution in the private rental market is \$9,880 on an annual basis. Hence, we include the rental expenditure on the minimum rental size as a target and match it to the above expenditure. Changes in h_{min} have a large impact upon the ability of younger households to purchase housing due to the presence of credit constraints. So we include the home ownership rate for households under the age of 35 as a target moment. Lastly, the scale parameter for housing production function, ψ_1, largely determines the total size of housing stock. To calibrate this parameter we include the median house value in the SIH normalised by the median household income.

The parameter φ in the definition of NRI in (8) determines the ability of landlords to deduct rental interest expenses from taxable income. This parameter is closely related to the share of investment mortgage loans to total mortgage loans held by landlords, so we include this moment as a target. The final parameter to calibrate is the standard deviation of the depreciation shock, σ_ω. This parameter influences the share of interest expenses to total expenses on investment housing. A higher value of σ_ω leads to a larger share of depreciation costs and hence a smaller share of mortgage interest payments to total expenses. As a result, we include this data moment among our targets. Both φ and σ_ω play an important role in determining the fraction of negatively geared landlords, which is an important moment to

Table 4: Target moments for internal calibration

Target Moment	Model	Data	Source
Overall home ownership rate	0.70	0.69	SIH 2013-14
Home ownership rate for under 35	0.33	0.37	SIH 2013-14
Home ownership rate for 65+	0.80	0.84	SIH 2013-14
Minimum rental expenditure	0.15	0.15	SIH 2013-14
Loan-to-value ratio (median)	0.48	0.49	SIH 2013-14
Rent-to-income ratio (median)	0.25	0.25	SIH 2013-14
Fraction of landlords	0.15	0.13	SIH 2013-14
Fraction of negatively geared landlords	0.53	0.59	ALife
Share of investment loan to total loan for landlords (median)	1.00	0.98	ALife
Ratio of interest to total expense on invest. housing (median)	0.56	0.50	ALife
Median house value	3.24	3.28	SIH 2013-14

Notes: The minimum rental expenditure and the median house value are normalized by the annual median household income.

match for the purpose of this study.[26] We therefore include it as a target moment as well.

Table 3 summarises the estimated values of our internally calibrated parameters. Table 4 summarises the target moments that are used in the calibration and the corresponding model-implied values. In general, the model does a good job in fitting the data. We highlight the value of a few key parameters that are estimated in this procedure. First, the standard deviation of the depreciation shock, σ_ω, is estimated to be 0.071. This value is comparable to what has been used in the existing literature.[27]

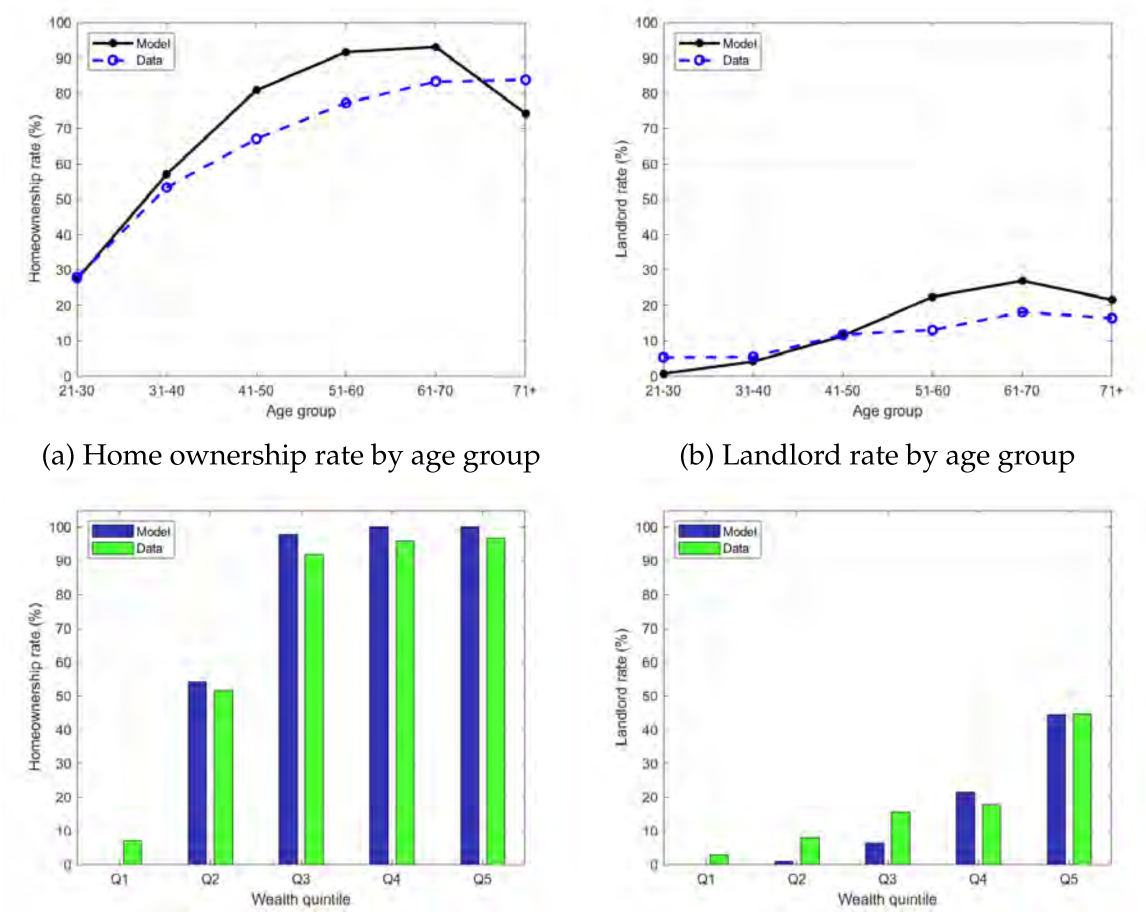
The value of the two-year discount factor β is estimated to be 0.85, which corresponds to a one-year value of 0.92. This is lower than in some studies but similar to values used in other OLG models with housing including Graham (2021) and Jeske et al. (2013). Finally, we note that φ, the percentage of investment housing that may be financed by debt is 0.982. This is a high value but consistent with the observation in Section 3 that a significant proportion of landlords in the Australian economy only have investment housing debt and do not have debt associated with owner-occupied housing.

5.3 Quantitative properties of the baseline model

We present some important quantitative properties of the baseline steady state. Where possible, we compare them to the corresponding data moments to provide further validation of the calibration. Additional quantitative properties are in Appendix C.1.

[26] In Appendix D.2, we calibrate a version of the model without the housing shock and find that the model implies a much lower fraction of negatively geared landlords. As a result, the quantitative effects of removing negative gearing are much smaller.

[27] Jeske et al. (2013), Mitman (2016), and Gete and Zecchetto (2017) use values of this parameter in the range of 6% - 10%, based on FHFA data.



(a) Home ownership rate by age group (b) Landlord rate by age group

(c) Homeownership rate by wealth quintile (d) Landlord rate by wealth quintile

Figure 4: Home ownership and landlord rates by age group and wealth quintile

Notes: Data values are from the SIH 2013-14.

Home ownership and landlord rates. Figure 4 depicts the home ownership rate and landlord rate by age group (panels (a) and (b)) and by wealth quintile (panels (c) and (d)). The corresponding data values from SIH are also displayed. The model generates a life-cycle profile of home ownership rate similar to that observed in the data where the home ownership rate increases from 27% for the first five cohorts (ages 21-30) and reaches the peak of 92% for cohorts between age 61 and 70. The model slightly underestimates the landlord rate for the young and slightly overestimates the landlord rate for older households. Nevertheless, it exhibits an increasing trend with age, as observed in the data. The model also matches the positive association of home ownership and landlord rates with household wealth.

LTV ratios for homeowners and landlords. Figure 5 shows that the model does a good job in matching the average LTV ratios for homeowners and landlords in the data (SIH) by age group (top panel) and by income quintile (bottom panel). Although landlords tend to

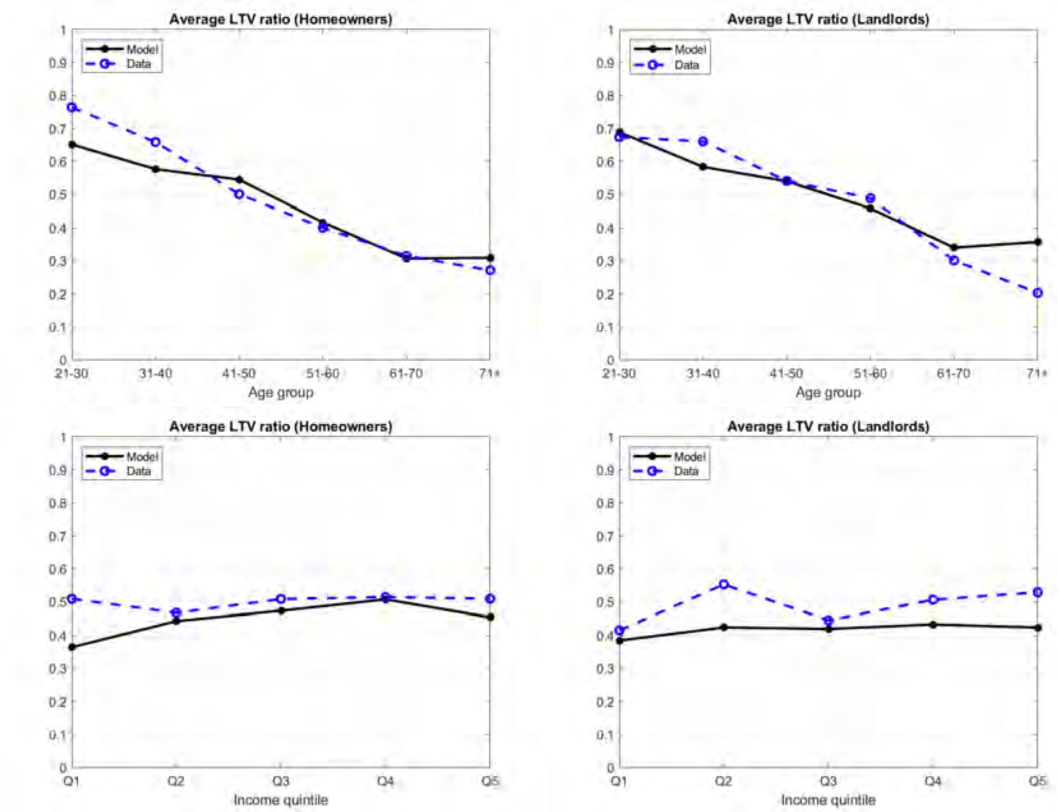


Figure 5: Average LTV ratios by age group and income quintile

Notes: Data values are from the SIH 2013-14.

hold more housing assets, they have similar levels of LTV ratios as homeowners. As households get older, they accumulate more wealth and hold less mortgage debt. As a result, the level of average LTV ratio declines with age, as shown in the top panel. The model slightly underestimates the average LTV ratio for young homeowners and overestimates it for old landlords. The bottom panel shows that the average LTV ratios remain relatively constant across income quintiles, both in the model and in the data.

Distribution of negatively geared landlords. In order to draw realistic policy implications, it is important for the model to replicate the behaviour of landlords particularly with respect to their usage of negative gearing as discussed in Section 3. In our baseline steady state, 53% of landlords are negatively geared. This is slightly below the fraction of negatively geared landlords observed in the data, which is about 59% in 2013-14. Nonetheless, Figure 6 shows that the model replicates the declining use of negative gearing as landlords age and the increasing use as income increases.

Distribution of housing consumption and housing ownership. The left panel in Figure 7 displays the distribution of consumption of housing services for both homeowners and renters and the right panel displays the distribution of housing stock ownership. Figure 7

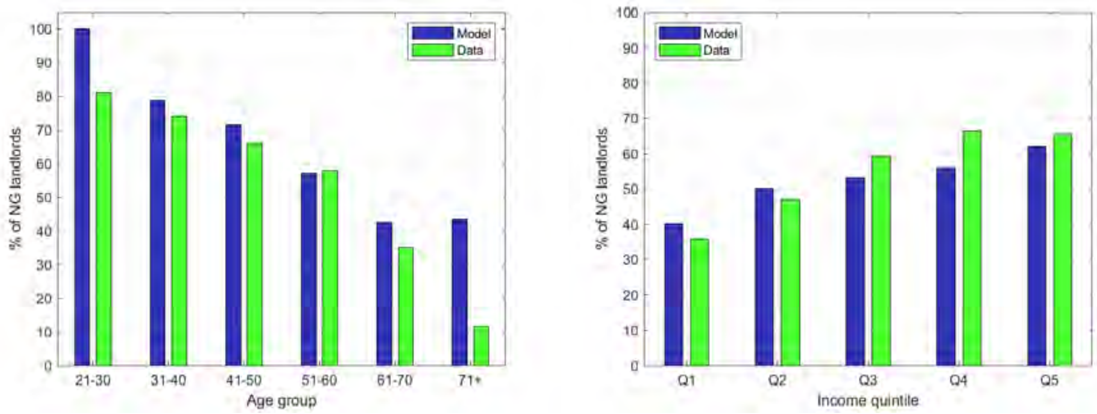


Figure 6: Fraction of NG landlords by age group and income quintile

Notes: The data values are previously displayed in Figure 1. They are from the ALife Database.

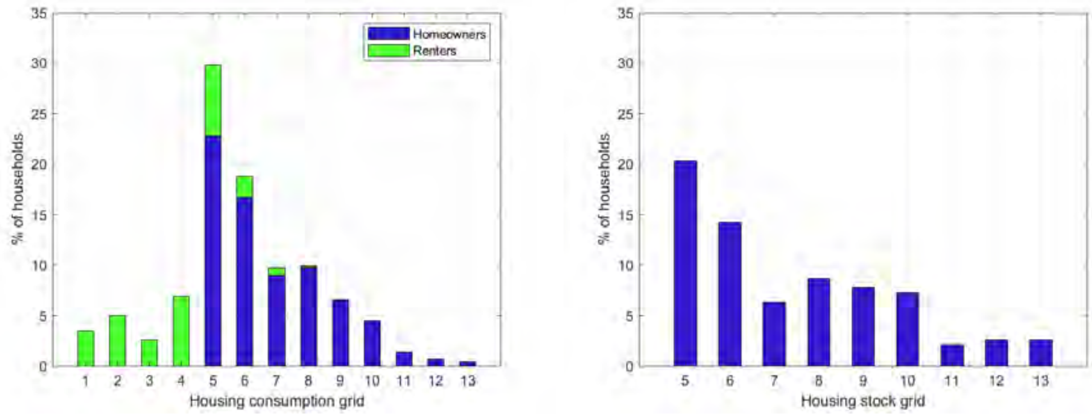


Figure 7: Distribution of housing consumption (left panel) and housing ownership (right panel)

Notes: The horizontal axes represent housing consumption and housing stock grids, which are ordered from smallest to largest.

shows that many homeowners own the smallest sized house suggesting that the minimum purchase size of housing is binding and affects household behaviour. It also suggests that many renters are credit constrained and are only able to enter the purchase market by buying small houses. The maximum size of housing does not seem to constrain households. Few households own the largest houses and renters do not consume larger houses even though they are allowed to do so.

Transition rates. Transition rates between different housing tenure states are calculated in Cho, Li and Uren (2021) using the HILDA survey. Households that move house are classified into one of four transition categories: 1) owner-to-owner (O2O); 2) renter-to-owner (R2O); 3) owner-to-renter (O2R); 4) renter-to-renter (R2R). The O2O and O2R transition rates are calculated as the total O2O and O2R transitions divided by the number of homeowners in

Table 5: Annual housing transition rates and landlord persistence

	Model	**Data**
O2O	0.027	0.025
R2O	0.062	0.052
O2R	0.019	0.021
R2R	0.237	0.147
Landlord persistence	0.852	0.885
NG landlord persistence	0.597	0.746

Notes: The data values for transition rates are mean values over the period of 2001-2017 in HILDA. The data values for landlord persistence are mean values over the period of 2001-2018 in ALife.

the previous year. Similarly, the R2O and R2R transition rates are calculated as the total R2O and R2R transitions divided by the number of renters in the previous year. Table 5 report these transition rates in the model and the data. The model O2O, R2O, and O2R transition rates closely match the data counterparts; R2R transition rates are underestimated.[28]

Since we are able to match the transition rates involving owner-occupied housing, it is not surprising that our model also does a reasonable job in matching the average duration of home ownership. In the HILDA survey, owner-occupied households live in the same house for 14.3 years on average compared to 12.5 years in our model.

The last two rows of Table 5 report the annual persistence in landlords and negatively geared landlords in the model and in ALife. The persistence in (negatively geared) landlords is the fraction of (negatively geared) landlords who remain (negatively geared) landlords in next period. The model does well in generating a reasonable amount of persistence in landlords but understates the persistence in the use of negative gearing.

6 Removing Negative Gearing

This section presents the quantitative impact of removing negative gearing concessions. We first compare the differences in steady state outcomes between the baseline and a counterfactual economy. In the baseline, investment housing expenses are fully deductible so taxable income is given by (9). In the counterfactual economy, investment housing expenses are partially deductible so taxable income follows (10). The removal of full deductibility increases tax revenue. We study three ways in which this additional government revenue can be used: (1) the government redistributes additional tax revenue equally to all households via a lump-sum transfer; (2) the government redistributes additional revenue by providing a fixed payment to renters only, which we interpret as rental assistance; and (3) the govern-

[28]We do not view the discrepancy between the model and the data in R2R transition rates as an issue. A model in which renters experience a moving shock that forces them to move to a new rental property with similar size at no cost would be identical to our current model but with a higher R2R transition rate.

ment maintains revenue neutrality by reducing the marginal income tax rates by an equal proportion.[29] In case (3), reducing all marginal income tax rates by 2.5% preserves revenue neutrality. We study dynamic effects in Section 6.3.

6.1 Steady state comparisons

Prices and quantities. Table 6 compares the baseline steady state to that of the counterfactual economies. The steady state response when the additional tax revenue is distributed as a lump-sum transfer or used to reduce income tax rates is quite similar. In both experiments the equilibrium quantity of investment housing and the landlord rate fall substantially, by around 14% and 26%, respectively. The decline in demand for investment housing reduces aggregate housing demand, and thereby reduces the house price and raises the rent. In response to the fall in house price, the aggregate housing supply also declines. In the lump-sum transfer experiment, the magnitude of the increase in rents (2.5%) is larger than the magnitude of the decline in house price (0.9%) and total housing supply decreases by around 1.8%. In the income tax experiment, the effects on rents are similar but the effect on house prices and housing supply is more muted.

Turning to the home ownership rate, we find that it increases by 2.6 and 1.8 percentage points in the lump-sum transfer and income tax experiments, respectively. The following mechanism is at work. The fall in house price and the rise in rent reduces the price-to-rent ratio by about 3.2%, which promotes home ownership. Younger households are also restricted from buying houses by downpayment constraints and transaction costs. The decline in house prices relaxes these constraints and there is a significant increase in home ownership among households under the age of 35; their ownership rate increase by 3 percentage points.

The impact upon steady state outcomes differs when additional tax is redistributed as a rental assistance. Removing full deductibility hurts landlords and, other things equal, reduces the willingness of households to supply rental housing. But the subsidy to renters encourages rental demand and has a strong effect on rental price. The net result is that the equilibrium rental price and quantity of houses rented increase significantly from baseline levels, by 4% and 8%, respectively. This composition of landlords also shifts to those who are richer and rely less upon negative gearing. There is still a decline in the purchase price as households shift from owner-occupied to rental housing but it is moderated relative to other experiments.

Negatively geared landlords and debt As reported in Table 6 the proportion of negatively

[29] Three additional counterfactual policy experiments are discussed in the Appendix C.4. These experiments are: (1) partial removal of negative gearing where landlords can deduct 50% of the loss incurred from their housing investment; (2) complete removal of negative gearing along with 25% discount on capital gains tax; (3) retain negative gearing but allow for removal of capital gains tax discount.

Table 6: Removing negative gearing: policy experiments

	Baseline	Counterfactual		
		LS transfer	Income tax	Rent. assist.
Price	3.139	3.110	3.118	3.128
Rent	0.538	0.551	0.552	0.560
Price-rent ratio (annual)	11.67	11.28	11.30	11.18
Overall home ownership rate	0.697	0.723	0.715	0.688
Home ownership for under 35	0.334	0.364	0.368	0.334
Landlord rate	0.145	0.107	0.108	0.128
Frac. of NG landlords	0.525	0.359	0.381	0.338
Average LTV ratio	0.455	0.451	0.445	0.453
Average DTI ratio	1.088	1.012	1.014	1.057
Total housing supply (normalised)	1	0.982	0.987	0.993
Share of rental housing (%)	16.5	14.3	14.6	17.9
Total tax revenue (normalised)	1	1.011	1	1.014
Avg. tax paid by a landlord	0.269	0.274	0.276	0.289
Transfer/Rental assistance	-	0.003	-	0.011
Ex-ante *cev* (%)	-	0.13	-0.30	1.45

Notes: The average LTV and DTI ratios are averages across households with a positive amount of debt. The total housing supply and tax revenue are normalised relative to baseline steady state.

geared landlords falls significantly, by between 14 to 19 percentage points, in the counterfactual steady states. In Figure 8, we compare the distribution of negatively geared landlords between the baseline and the counterfactual steady states. The left panel shows that the decline in the fraction of negatively geared landlords is more significant for younger age groups: the fraction decreases by almost 50% for those aged 21 to 30 in the lump-sum transfer and income tax experiments. The right panel of Figure 8 shows that the decline in negatively geared landlords is larger among the highest income quintile, and the proportion of negatively geared landlords become more evenly spread across household income.

The removal of full deductibility also reduces the incentive for households to accumulate debt. This is reflected in a decline in the average LTV and DTI ratios in all of our experiments. The size of these declines are largest in the lump-sum transfer and income tax cases and more moderate in the rental assistance case. In the rental assistance case, there is more housing investment than in other experiments and interest expenses on investment housing debt are still partially deductible. This helps explain greater use of debt in this case.

Taxation and transfers. Table 6 also compares the total tax revenue collected by the government and the average tax paid by a landlord per period. The total tax revenue increases by 1.1 and 1.4% in the lump-sum transfer and rental assistance experiments, respectively. Removing full deductibility increases the average tax paid by a landlord by approximately 2% in the lump-sum transfer and income tax experiments, and 7% in the rental assistance experiment. The larger increase in the rental assistance experiment results from a larger increase in the rental price and a higher rental supply. When the additional tax revenue is distributed

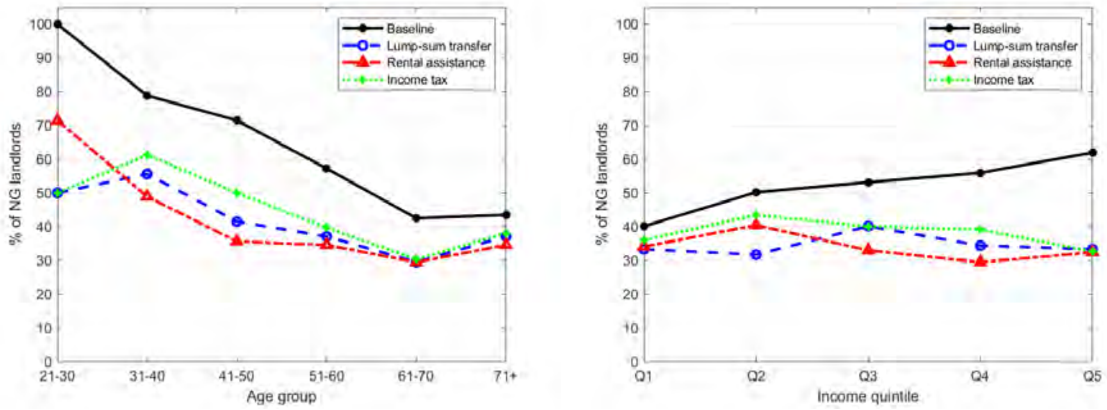


Figure 8: Percentage of NG landlords by age (left) and income (right)

Notes: The figure compares the fraction of negatively geared landlords in the baseline steady state and in our counterfactual experiments by age (left panel) and income quintile (right panel).

as a lump-sum transfer, every household receives a transfer payment that is equal to 0.3% of the median household income. In the rental assistance experiment, every renter receives a payment of 0.011, which corresponds to 2% of renters' median income.

6.2 Steady state welfare

As common in the literature, see Conesa, Kitao and Krueger (2009), our welfare analysis is based on the notion of consumption equivalent variation (*cev*) extended to consider housing services and bequest. That is, we calculate the required percentage change in the life-time consumption of non-durables, housing services, and bequest in the baseline economy that equates the expected discounted utility of this economy with that of a counterfactual economy. For the steady state welfare comparison, we consider the *ex-ante cev* of newborns who enter the economy with zero assets. Formally, the *cev* for a newborn with state vector $x \equiv (1, z, 0, 0, 0)$ is given by

$$cev(x) = \left[\frac{V^{cf}(x)}{V(x)}\right]^{\frac{1}{1-\sigma}} - 1, \tag{15}$$

where $V(x)$ and $V^{cf}(x)$ are the expected life-time utility for a newborn in the baseline and counterfactual economies, respectively.[30] A positive $cev(x)$ implies that a newborn with income shock z would prefer to be born in an economy without full deductibility. Averaging $cev(x)$ over the stationary distribution of z provides a steady state welfare measure.

As shown in Table 6, the removal of negative gearing leads to a small steady state welfare gain of 0.13% in the lump-sum transfer experiment and a much larger welfare gain of 1.45% in the rental assistance experiment. However, the income tax experiment incurs a welfare

[30]See Appendix B.4 for the derivation of this expression.

loss of -0.3%. This highlights that the manner in which additional tax revenue is used is important in determining the welfare impact of removing negative gearing.

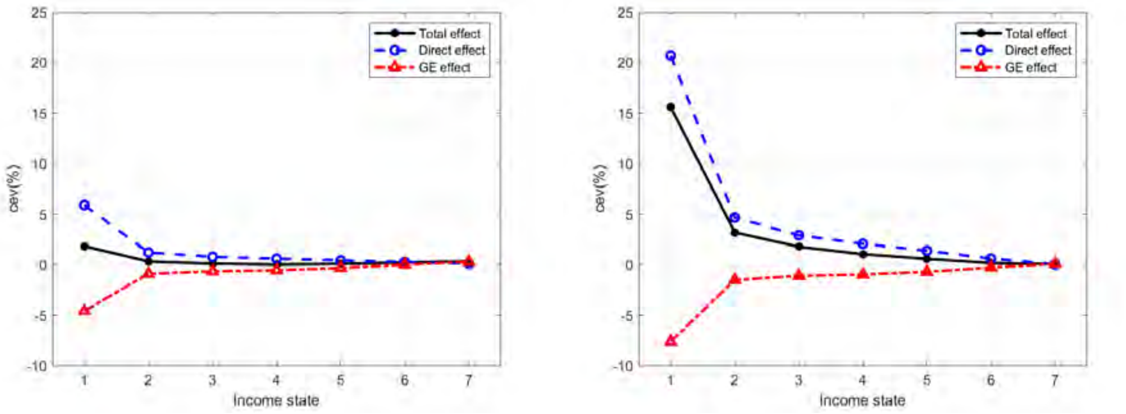
Next, we discuss the welfare results in more detail to identify the source of welfare changes. First, we decompose the welfare effects into a direct effect that arises due to changes in tax policy and a general equilibrium effect that arises due to changes in prices. Second, we study how alternative policies implicitly insure households against housing and income risk. This implicit insurance is a means by which the government can help minimise the welfare costs of missing markets. Third, we investigate how different policies affect the allocation of resources over time.

Direct vs. general equilibrium effects. To understand the steady state welfare results we decompose changes in welfare into two components: a direct effect and a general equilibrium effect. The direct effect examines the welfare change that arises from a change in tax policy while keeping prices fixed at their baseline level; the tax policy change includes both the removal of negative gearing and the subsequent redistribution of income in the counterfactual experiment considered. The general equilibrium effect keeps tax policy fixed as in the baseline economy but evaluates steady state welfare using equilibrium prices implied by the counterfactual economy. For both the direct and general equilibrium effect, welfare is evaluated for newborns conditional on initial income as in Equation (15) and the results for the lump-sum transfer and the rental assistance experiments are presented in Figure 9.[31]

There are several insights. First for newborns with high income the total effect on welfare is small. Second, the general equilibrium effect is detrimental to newborn households. They enter the economy as renters and the increase in rental price has a negative impact that is not fully offset by the decline in the purchase price of homes. This is particularly true for low-income households who remain renters, on average, for a longer time. Finally, the direct effect of policy changes benefit all households and especially low-income households. This positive effect is able to fully offset the negative general equilibrium effect, leading to a steady state welfare gain in both cases. The positive direct effect is substantially larger in the rental assistance case, contributing to a much larger steady state welfare gain in this case.

Insurance premia. One source of market failure in our model is the absence of markets to insure risk. To examine how different tax policies affect the valuation of risk, we calculate the amount a newborn would be willing to spend to eliminate the housing risk under each tax policy. We define these amounts as the housing insurance premia. If the tax system increases the provision of a particular type of implicit insurance (income or housing), then we posit that the willingness of a household to pay for private insurance of that type of

[31] For the income tax experiment (which are not displayed here), the general equilibrium effect is similar to the lump-sum transfer case, but the negative impact on low-income households is larger. The positive direct effect is smaller than in the lump-sum transfer case for most households, and exhibits an increasing relationship with income.



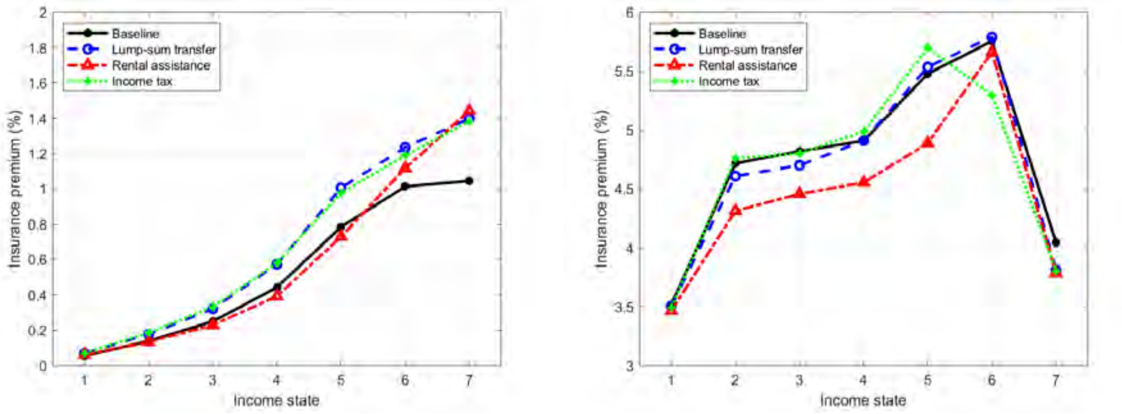
(a) Lump-sum transfer (b) Rental assistance

Figure 9: Decomposition of welfare gains from the removal of negative gearing

Notes: The figure displays the average *cev*s for newborn households as a function of initial income state. Income states are ordered from lowest to highest. The black solid line shows the total effect; the blue dashed line shows the direct effect where we fix the level of prices at the baseline steady state but allow transfers and taxes at the level of the counterfactual equilibrium; the red dashed line shows the general equilibrium effect where we maintain the baseline tax policy but assume counterfactual prices.

will decline. To implement this procedure, in the baseline and counterfactual economies, we solve for the value function of a newborn household when housing shocks are absent but prices are fixed at their equilibrium levels. This reveals how much utility would increase, in each scenario, in the absence of housing shocks. We then calculate the insurance premia in *cev* units to eliminate housing shocks (see Appendix B.5 for details). We follow an analogous process to calculate the insurance premia for income risk by calculating the value function of a newborn when income shocks are absent ($u_{i,a} = 0$ in Equation (4)). The resulting insurance premia are presented in Figure 10.

We highlight a number of points related to the housing insurance premium. First, the housing insurance premium is increasing in the initial income of a newborn household; high-income households are more likely to become homeowners and face idiosyncratic housing shocks. Second, the housing insurance premia are, for the most part, smallest for the baseline economy with full deductibility. This is particularly true for newborns with the highest income that are most likely to become landlords. The removal of full deductibility increases the willingness of households to pay to eliminate housing risk, as indicated by the higher insurance premia for the counterfactual economies. We view this as evidence that full deductibility may improve welfare by implicitly providing insurance to landlords that is missing in regular insurance markets. Third, examining the housing insurance premia in our counterfactual experiments, we find that in the lump-sum transfer and income tax experiments the insurance premia are significantly higher suggesting that the removal of full deductibility lowers implicit government insurance and raises the value of private insurance. On the other hand, the premium in our rental assistance experiment is more similar



(a) Housing risk

(b) Income risk

Figure 10: Insurance premia for newborn households by income state (income increases with income state).

to the baseline case. In the rental assistance case, with the larger increase in rental price, owners are better insured against shocks as they have the option to rent out housing.

With regards to the income insurance premia, we find that in the rental assistance case the insurance premium is significantly smaller than in other experiments. This follows since households that receive negative income shocks are likely to remain renters. Hence, rental assistance is a means via which the government can provide income insurance in an indirect fashion. This indirect government insurance lowers the value of privately insuring income and helps alleviate the welfare costs of missing insurance markets. When comparing housing and income insurance premia, the magnitude of the difference in the value of income insurance between the rental assistance case and other cases is much larger than the differences associated with the housing insurance premia. In sum, these results suggest that full deductibility does provide more insurance against housing shocks than other policies, as suggested in Section 2. However, the value of this additional housing insurance is small compared to the value of the income insurance provided in the rental assistance case.

Intertemporal wedge for renters. We identify a second potential source of misallocation of resources by studying the intertemporal wedge in consumption. In a setting without transaction costs, credit constraints, taxation, and minimum housing sizes, a household would satisfy a standard Euler equation linking their marginal utility from consumption in the current period to their marginal utility from consumption in the next period. For renters who will continue to be renters in next period, this equation is:

$$U'(C_t) = \beta(1+r)E_t\left[\kappa_a U'(C_{t+1}) + (1-\kappa_a)\nu'(\mathrm{b}_t)\right],$$

where the expectation is taken with respect to income and mortality shocks, C_t is the Cobb-Douglas aggregate of housing and non-durable consumption and $U(C) = \frac{C^{1-\sigma}}{1-\sigma}$, and the

Table 7: Mean values of the intertemporal wedges for renters (%)

Age group	**Baseline**	**LS transfer**	**Income tax**	**Rent. assist.**
21-30	19.60	18.79	19.89	17.96
31-40	3.82	5.04	4.65	3.74
41-50	5.83	5.22	5.34	5.69
51-60	4.42	3.73	3.76	5.15
61+	2.21	2.90	3.21	3.91
overall	12.02	11.88	12.38	11.30

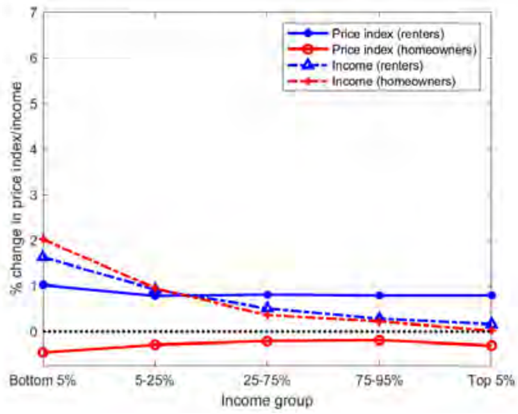
bequest b_t is simply the current savings of the renter. The presence of distortions in our economy implies that this condition will not hold with equality. Instead,

$$U'(C_t) = \left\{\beta(1+r)E_t\left[\kappa_a U'(C_{t+1}) + (1-\kappa_a)\nu'(\mathrm{b}_t)\right]\right\}(1+\xi)$$

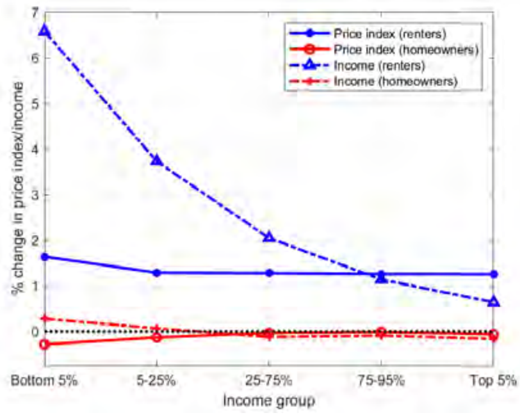
where ξ represents a deviation from what we would expect in a frictionless setting. Here, a positive value of ξ implies that households have a relatively high marginal utility of consumption today relative to the marginal utility from saving a unit of income today, investing in the risk-free asset, and consuming the returns from saving in next period. Equivalently, households would benefit by reallocating consumption from later to earlier in their life cycle but are prevented from doing so by credit constraints.

Table 7 presents a measure of the intertemporal consumption wedge for renters in the baseline and counterfactual economies.[32] We highlight a few points. First, the wedge for renters tends to be positive on average across all simulations. Second, the intertemporal wedge tends to decrease with age. As households age, they accumulate financial assets and the size of the wedge tends to decline. Third, when we look across counterfactual experiments, the rental assistance economy features a larger reduction in the overall size of the wedge (relative to baseline) and a particularly large decline for the youngest households that are most affected by credit constraints. The effect on the wedge is relatively minor in the lump-sum transfer experiment while reducing income taxes leads to an increase in the size of the wedge for the youngest households. These differences suggest that removing full deductibility and using the additional revenue to fund rental assistance leads to the largest improvement in the allocation of consumption over time. The lump-sum transfer experiment leads to a small improvement (on average) and the income tax case worsens the allocation of consumption over time (on average) relative to baseline.

[32]For this exercise, we focus upon renters since they are the households in the economy most affected by the credit constraints. The Euler equation for owners are more complicated since they depend upon the method of finance and tax rates in a more complicated fashion. The results in Table 7 are based on a matched sample of households across the four simulated steady states for the baseline and counterfactual economies, which consists of renters with the same age, income and savings who choose zero housing asset for next period. This matched sample covers about 80% of the renters in the simulated steady states.



(a) Lump-sum transfer



(b) Rental assistance

Figure 11: Percentage change in price index and income from the baseline economy

Notes: This figure depicts the percentage changes in required expenditure to reach baseline utility and the percentage changes in after-tax income for renters and homeowners across income groups.

Housing affordability. The removal of negative gearing also has implications for housing affordability. On one hand, changes in rental and purchase prices of housing affect expenditure on housing services. On the other hand, changes in prices and tax policy lead to income changes, which also affect housing affordability. To understand how price changes affect housing affordability we employ the concept of an expenditure function or a price index, which describes the expenditure required to achieve a certain level of utility, given prices.[33] We evaluate the expenditure function for each household at their per-period steady state utility and baseline prices. For renters, the price of housing is simply the rental price. For owners, we use a user-cost of housing approach to define the price of housing: this incorporates both the method of financing and the tax-free status of imputed rental income.[34] We then calculate for each household the percentage change in expenditure required to reach the same utility level under the new counterfactual prices. We do this on a matched sample of households that have the same states (and hence the same tenure status) in both the baseline and the counterfactual steady states.[35]

The average percentage changes in expenditure required to reach baseline utility by tenure status and income for the lump-sum transfer (left-panel) and rental assistance (right-panel) experiments are displayed in Figure 11. In both experiments, the rise in rent raises the expenditure required for renters to reach the baseline level of utility, suggesting a de-

[33]In Appendix C.3, we consider an alternative measure for housing affordability, the housing cost to income ratio, and compare it across experiments for renters and owners.

[34]See Appendix B.6 for formal details. Here, we note that in our calculation of the price index we focus upon per-period utility. A more complete measure of changes in housing affordability in a dynamic framework would study how sequences of prices affect the expenditure required to reach a certain expected discounted level of utility. We leave this issue for future research.

[35]The matched sample for the lump-sum transfer (rental assistance) experiment covers 75% (78%) of the population.

terioration in housing affordability for renters in the absence of income increases. The percentage increase in expenditure is the largest for poorest renters with income below the 5th percentile. Most of these households are renting the smallest unit of housing possible. As rent increases, households renting larger houses are able to substitute towards non-durable consumption and reduce their consumption of more expensive housing services. The poorest renters are unable to do so due to the minimum size constraint on housing. Hence, to achieve the level of utility attained in the baseline economy their expenditure has to increase by a greater amount. Comparing the two experiments, there is a larger increase in expenditure required to reach baseline utility in the rental assistance case due to the greater increase in rental price.

On the other hand, when looking at homeowners the fall in the purchase price of housing lowers their expenditure required to reach the baseline level utility. The fall in house prices is larger in the lump-sum transfer case, and implies the corresponding decline in expenditure required to attain baseline utility is larger in this case.

Figure 11 also depicts the percentage change in after-tax income for each experiment. The change in after-tax income reflects two factors: i) changes in prices, and ii) the removal of full deductibility and the accompanying revenue-neutral change (i.e., transfers) in the tax system.[36] If the change in after-tax income exceeds the change in expenditure required to attain baseline utility, households are likely to be compensated for price changes. In the lump-sum transfer experiment, only a small portion of renters experience increases in after-tax income that exceeds the change in required expenditure to maintain baseline utility. In contrast, for homeowners the changes in after-tax income are generally positive while the fall in house prices reduces the expenditure required to reach baseline utility. As a result, affordability for homeowners improves.

In the rental assistance case, transfer payments are targeted at renter so that the increase in after-tax income for renters are much larger than in the lump-sum transfer case. As a result, a majority of renters experience an increase in after-tax income that exceeds the increase in expenditure required to attain baseline utility. This is particularly the case for low-income renters, suggesting a significant improvement in their affordability. For homeowners, they may receive higher rental income but face higher taxes due to the removal of full deductibility. We find that after-tax income increases by a small amount for low-income homeowners (who are less likely to use negative gearing) and decreases by a small amount for high-income homeowners (who are more likely to use negative gearing).

[36] After-tax income is defined as the sum of labour income, interest income on financial assets, net rental income, and government transfers less taxes. When examining income changes for each household in the matched sample, we assume the household makes the same housing investment decision as in the baseline economy. Hence, only changes in prices and in the tax system affect after-tax income.

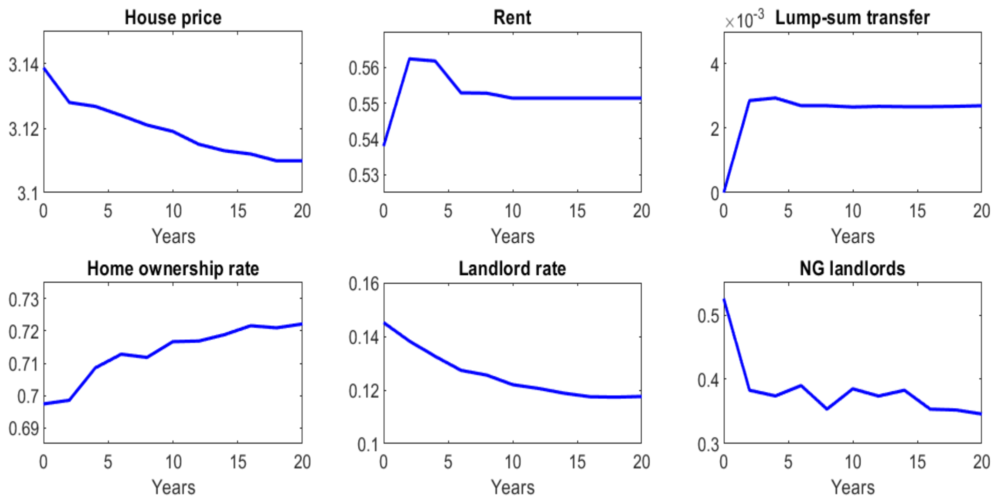


Figure 12: Transition path after the permanent removal of NG: lump-sum transfer

6.3 Transition dynamics

We now examine the dynamic effects of an unexpected and permanent removal of negative gearing. This will provide a more complete picture of the overall welfare impact. We focus upon the dynamic effects in the lump-sum transfer and rental assistance experiments. See Appendix E for a detailed description of the computational procedure for the perfect foresight transitional path.

Transition paths of variables. Figure 12 displays the transition path of key variables following the removal of negative gearing in the lump-sum transfer experiment.[37] The convergence from the baseline to the new steady state takes about 10 periods, i.e. 20 years. We observe that rent, the fraction of negatively geared landlords, and the lump-sum transfer transition to the new steady state quickly while the home ownership rate, the landlord rate, and house price change more gradually. Following the removal of full deductibility, rental price overshoots, increasing by 4.5% above baseline before declining to the new steady state level that is 2.5% above baseline.

Welfare effects on existing households. Along the transition path, our welfare measure calculates the *cev* for every household alive at the time of the unexpected repeal of negative gearing. Analogous to the steady state welfare measure, cev_i is the required percentage change in household i's consumption in their remaining periods of life in the baseline economy to generate the same expected discounted utility that they would receive in the counterfactual economy.[38] Averaging cev_i over the baseline steady state distribution of households

[37] The transition paths of variables in the rental assistance experiment have a similar pattern except that the home ownership rate decreases gradually to a slightly lower level.

[38] As in the steady state case, this increase in consumption includes non-durable consumption, housing consumption, and bequests.

Table 8: Welfare over transition: overall and by initial housing tenure

	Lump-sum transfer			**Rental assistance**		
	Mean (%)	Median (%)	$P(cev_i > 0)$	Mean	Median	$P(cev_i > 0)$
Overall	0.172	0.184	0.707	0.357	0.118	0.660
Renters	0.022	-0.032	0.433	1.049	0.792	0.934
Owner-occupiers	0.280	0.298	0.867	0.094	0.017	0.543
Landlords	0.034	0.092	0.597	0.083	0.149	0.604
NG landlords	-0.020	0.032	0.539	-0.047	-0.055	0.438

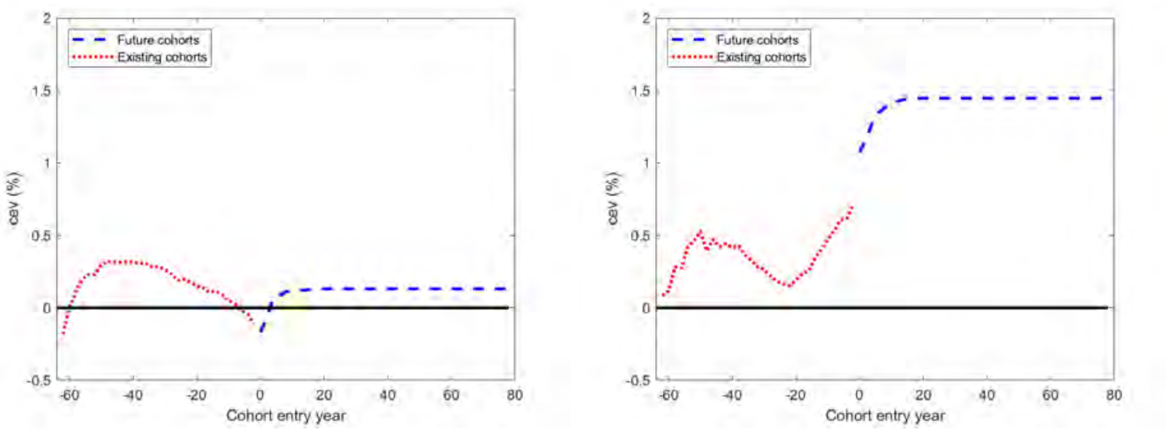
provides an average measure of the welfare change of households alive when the policy change is enacted.

The top panel of Table 8 reports the mean and median cev_i, as well as the proportion of households who benefit from the policy reform in the lump-sum transfer and rental assistance experiments. In both cases, there is an average welfare gain and a majority of households benefit from the reform. In the lump-sum transfer experiment, the average welfare gain is 0.17% compared to 0.36% in the rental assistance case. Despite the larger average welfare gain in the rental assistance case, there is a smaller median welfare gain and less households gain overall. To understand the mechanism underlying these results, we examine welfare outcomes across heterogeneous households.

The welfare effects by initial housing tenure are given in the bottom panel of Table 8.[39] In the lump-sum transfer case, owner-occupiers experience larger welfare gains than landlords and renters, and almost 90% of them benefit from the policy reform. Unlike landlords, owner-occupiers are not directly affected by the removal of full deductibility. The decline in house prices reduces their housing wealth, but makes it easier for them to transition to larger housing. They also benefit from the lump-sum transfer. In contrast, more than 50% of renters experience a welfare loss, suggesting that the transfer and an improved prospect of becoming a homeowner with lower house prices does not compensate for the rise in rents for these households. Note that immediately after the policy change, house price declines only by 0.35% while rental price increases by 4.5%. About 60% of landlords and slightly more than half of negatively geared landlords benefit from the policy change. Although they no longer enjoy full deductibility of investment housing expenses, they are compensated with higher rental receipts and transfer payments. However, some landlords experience large welfare losses as implied by the small positive mean *cev* for landlords and negative mean *cev* for negatively geared landlords.

In the rental assistance experiment, a similar mechanism is at work. However, the rise in rental price is larger than in the lump-sum transfer case, and the size of the transfer payment is larger since it is targeted at renters only. Hence, renters experience a much larger welfare gain than other groups, which is also much larger than the welfare gains in the lump-sum transfer case. The welfare gain to landlords is also larger than in the lump-sum transfer case.

[39]The welfare effects by initial income, wealth, and mortgage status are presented in Appendix C.5.



(a) Lump-sum transfer

(b) Rental assistance

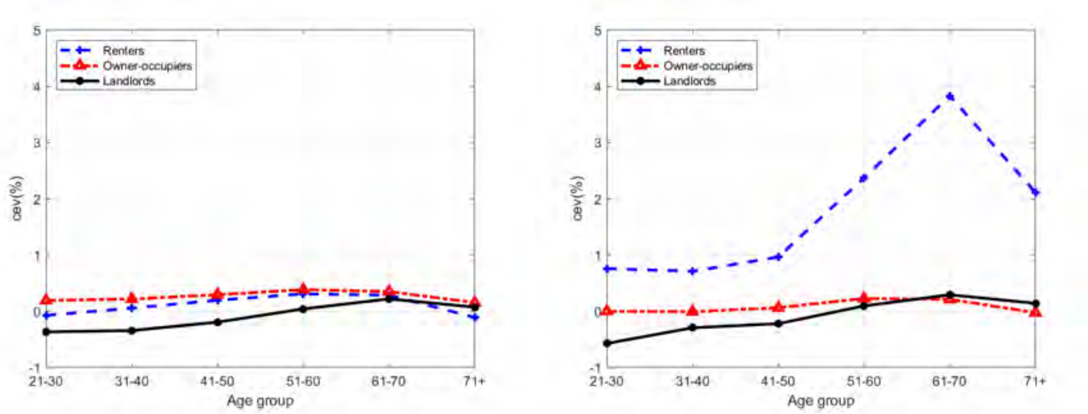
Figure 13: Welfare effects by cohort over the transition

Notes: The horizontal axis represents the entry year of cohorts where the value zero indicates the period in which the policy reform is implemented. A negative value on the x-axis indicates the number of years alive prior to the policy reform. A positive value on the x-axis indicates the number of years after the policy reform, before birth.

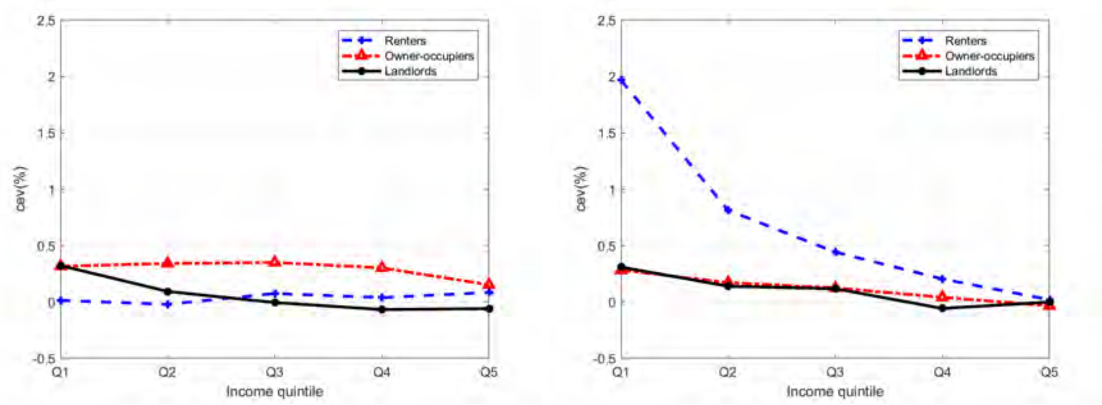
However, owner-occupiers experience a lower welfare gain and negatively geared landlords experience a larger welfare loss than in the lump-sum transfer case.

The welfare effects by age are illustrated by the red dotted line in Figure 13, where it depicts the average *cev* for each cohort alive at the time of the policy change (and for future cohorts to be discussed below). In the lump-sum transfer experiment, most existing cohorts experience a small welfare gain on average. Mid-aged households benefit the most as they are more likely to upsize housing and hence gain from the lower housing price. The youngest and oldest households bear a small welfare loss from the policy change. Young households are more likely to be renters and hence suffer from the rise in rent, while the fall in house price hurt old households who are less likely to upsize. In the rental assistance case, households of all ages benefit from the policy change on average and the welfare gains are generally larger than in the lump-sum transfer case. The welfare change is non-monotonic in age: the youngest households and household in the age range of 55-70 gain the most. Other households gain by less on average. This non-monotonic pattern reflects two main mechanisms. As cohorts age, there are fewer renters who experience large welfare gains. Countering this effect is that older renters gain the most from rental assistance (see panel (b) of Figure 14 below).

Finally, we examine the welfare effects by housing tenure status interacted with initial age or income. Panels (a) and (b) in Figure 14 illustrate the average cev_i by initial age and housing tenure status. Notably, younger landlords are hurt the most by the policy change in both experiments. Younger landlords are highly leveraged (Figure 5) and are more likely to be negatively geared (Figure 6). In the rental assistance case, renters of all age groups



(a) By age: lump-sum transfer (b) By age: rental assistance



(c) By income quintile: lump-sum transfer (d) By income quintile: rental assistance

Figure 14: Average cev_i by housing status interacted with age (top) and income (bottom)

are clearly the winners; the welfare gains are significantly larger than other groups and than welfare gains in the lump-sum transfer case. Older renters benefit the most because they are likely to remain renters and receive rental assistance until the end of their life.

Panels (c) and (d) in Figure 14 depict the average cev_i by housing tenure status and income quintiles. In both the lump-sum transfer and rental assistance experiments, landlords with higher income lose the most or benefit the least. As shown in Figure 6, high-income landlords are more likely to be negatively geared so removing full deductibility hurts these landlords more than other groups. We also find that, in the rental assistance experiment, low-income renters experience a significantly larger welfare gain.

Welfare effects on future generations. We also study the welfare effects on cohorts born during the transition. For each such cohort, we calculate the average ex-ante cev of newborns upon entry.[40] The computed cev for future newborns in the lump-sum transfer and rental assistance experiments are presented by the dashed blue lines in Figure 13. The welfare effects in both experiments share a similar pattern: welfare gains of future generations

[40]We follow a similar way as we compute the steady state welfare in Section 6.2 but replace the steady state value function, V^{cf}, with the value function for each cohort upon entry over the transition.

increase over time and gradually converge to the steady state level of welfare gain. The smaller welfare gain for cohorts born immediately after the policy change comes from the spike in rental price right after negative gearing is removed, as shown in Figure 12. In the lump-sum transfer experiment, newborns in the first two periods after the policy change suffer a welfare loss. It is also evident that the welfare gains for future generations are much larger in the rental assistance case, in the order of 1.6% to 2.15% of lifetime consumption, as compared with -0.25% to 0.19% in the lump-sum transfer experiment.

An aggregate welfare measure. Following Auerbach and Kotlikoff (1987) and Kindermann and Krueger (forthcoming), we define an aggregate welfare measure which takes into account households who are alive when the policy reform is implemented as well as future generations. For each household in the baseline steady state, we compute the amount of initial wealth transfer (i.e., change in their existing financial asset holdings), $\psi_0(x)$, needed to make them indifferent between the status quo and the policy change:

$$V^{cf}(a, z, \omega, s_{-1} + \psi_0(x), h_{-1}) = V(x), \quad x \equiv (a, z, \omega, s_{-1}, h_{-1}).$$

And for each cohort born in period $t \geq 1$ after the policy reform, we compute the initial wealth transfer, ψ_t, that would equate expected discounted utility in the counterfactual economy with that in the baseline economy:

$$\mathbb{E}\left[V_t^{cf}(1, z, 0, \psi_t(x), 0)\right] = \mathbb{E}\left[V(1, z, 0, 0, 0)\right], \quad x \equiv (1, z, 0, 0, 0),$$

where the expectation is with respect to the initial income realization. We then calculate the total present discounted value (using the risk free rate as the discount factor) of all transfers for currently living households and future generations and convert it into a consumption flow measure, as described in Kindermann and Krueger (forthcoming).

We calculate this aggregate welfare measure for the lump-sum transfer and rental assistance experiments, and find a small welfare gain of 0.2% for the lump-sum transfer case and a much larger welfare gain of 2.6% for the rental assistance case. This measure takes into account all generations affected by the policy change. For the rental assistance case, it suggests that the welfare gains from the removal of full deductibility of investment expenses is not simply due to the redistribution between different generations. Rather, the changes in tax policy affect welfare by leading to a more efficient allocation of resources.

7 Conclusion

In this paper, we highlight that there is a significant amount of risk associated with investment housing. Full deductibility of investment expenses from taxable income can partially alleviate the lack of insurance markets for housing investment. Despite that, we find that removing full deductibility of investment housing expenses can lead to aggregate welfare gains when the revenue raised from removing full deductibility is used to provide a lump-sum transfer to renters. These welfare gains occur when comparing steady states and over the transition path.

Welfare increases in our rental assistance experiment for a couple of reasons. First, rental assistance provides insurance against negative income shocks. Households that remain renters for the longest time have typically received poor labour market outcomes so rental assistance is an indirect method of providing income insurance. Second, rental assistance transfers resources to young households that may be credit constrained. By increasing income of the young, this policy may loosen credit constraints and improve the allocation of consumption over time. Other uses of revenue we consider, such as a lump-sum subsidy paid to all households or a reduction in income tax rates provide smaller welfare gains or welfare losses and are shown to be less effective in providing insurance against risk or leading to a more efficient allocation of consumption over time.

We conclude with a discussion of some additional issues. In our model, owning a house allows a household to access debt subject to a LTV and DTI constraint. This ability to borrow provides a degree of insurance against income or housing shocks. In reality, housing debt is linked to a mortgage that often has specific repayment terms that can only be refinanced at some cost. Boar, Gorea and Midrigan (forthcoming) argue that mortgages are inflexible and many homeowners are liquidity constrained due to the presence of scheduled repayments and refinancing costs that are absent in our model.

There are a number of potential extensions to this paper. The current model focuses on a stationary equilibrium where ex-ante capital gains on housing are absent. Given the recent long boom in the Australian housing market, it may be natural to relax this assumption and consider environments with growth in housing prices, which can be an important consideration in housing investment decisions. The challenge with this extension is that it removes stationarity from the household decision making process. Second, potentially there are differences in short-term and long-term investors that may be interesting to study. The removal of negative gearing may affect different types of investors in different ways. Finally, our paper discusses the implications of a complete removal of negative gearing. There are other options: the Labor Party considered removing full deductibility for existing houses but retaining it for new homes. Such a policy is sensible in that it would help to encourage the supply of new housing but are difficult to model explicitly, as it would require expanding the state vector to include ownership of newly built housing as well as established housing.

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Appendix for Online Publication

A Data

A.1 Survey of Income and Housing

The empirical moments of the housing market in Australia, including the fractions of home-owners, landlords, loan-to-value, and rent-to-income ratios are computed from the Survey of Income and Housing (SIH) published by the Australian Bureau of Statistics (ABS). The SIH contains a representative sample of Australian households and the ABS conducts the survey for every two years. It is a repeated cross-section dataset, and we use the 2013-14 release for our steady state calibration. The only sample restriction we apply is the age of households, where we keep household heads whose age is 21 or above. Our final sample consists of 14,044 households. The SIH has a variable for households' housing tenure status and we use this variable to calculate the average home ownership rate. The landlord rate is calculated from the variable asking the respondents, *'the number of residential properties owned (excluding selected dwelling) that are rented'*. The survey has information on the remaining mortgage balances on households' primary dwelling and investment properties. We use these information along with the self-reported housing values for the respective property type to calculate the loan-to-value ratios for homeowners and landlords. The rent-to-income ratio is computed from the weekly rents paid by renting households and the household level income, both are adjusted for the two-year model period.

A.2 ALife

The ALife Database is administrative data provided by the Australian Taxation Office (ATO). It contains information on the tax returns of 10% of Australian taxpayers and follows these taxpayers over time. For our purposes, we use the information on rental income and expenses contained in the ALife Database. Expenses are divided into interest expenses, deductions related to capital works, and other deductions. We focus upon individuals who are at least 21 years old. Landlords are defined as individuals that have more than $3,120 of rental income in a year. The bottom one percent of rental expenditure by households in the SIH is $6,240 so we only include landlords whose income is more than half of the rental expenditure of the bottom one percent of the rental expenditure distribution.

A.3 Household Income and Labour Dynamics

The Household Income and Labour Dynamics (HILDA) is a longitudinal survey that is nationally representative. The survey started in 2001 and is conducted on an annual basis. A total of 7,682 households, consisting of 19,914 individuals, participated in Wave 1, and from Wave 11 onwards, an additional 2,153 households were added to the survey. The survey contains information on household income, consumption, wealth, and other demographic variables.

Our sample consists of households who are aged between 21 and 84. Since our analysis only requires one member from each household, we drop children under 15, dependent student, non-dependent child, other family members who are not related to a couple or involved in a parent-child relationship. Information on housing tenure is important for our analysis. We thus drop those households with missing information on such a variable. Households who reported the value of their housing less than AUD 10,000 or whose value has been top-coded are also dropped. In total, our sample consists of 10,491 households with 67,871 observations.

B Derivation and Definition

B.1 Risk and investment decisions

We expand on our discussion of investment decisions by including uncertainty in housing investment returns and risk aversion. Suppose households are risk averse with a utility function with the following properties: $u'(c) > 0$ and $u''(c) < 0$. Further assume that there is some risk in rental housing investment. This could take the form of uncertainty in R which is rental income less expenses other than interest payments. For concreteness, assume $R = R_L$ with probability π_L and $R = R_H$ with probability $1 - \pi_L$ and that without loss of generality, $R_H > R_L$ and further assume $R_H - pr_b > 0 > R_L - pr_b$ so that the investor makes a profit in the good state of the world and a loss in the bad state of the world. The expected utility of a household that finances their investment using debt assuming full deductibility of investment housing expenses is:

$$EU_{FD} = \pi_L u((1-\tau)(y + R_L - pr_b)) + (1-\pi_L)u((1-\tau)(y + R_H + pr_b)).$$

If investment housing expenses are partially deductible the payoff for an investor in this situation would be:

$$EU_{PD} = \pi_L u((1-\tau)y + R_L - pr_b)) + (1-\pi_L)u((1-\tau)(y + R_H + pr_b))$$

where clearly $E_{FD} > E_{PD}$ so given a particular project, households would have a greater incentive to invest under a system with full rather than partial deductibility of expenses.

Our final point is that a social planner may want an investor to develop housing if the expected rental income from housing exceeds the cost of housing. In our setting, this would be satisfied if,

$$\pi_L(R_L - pr_b) + (1 - \pi_L)(R_H - pr_b) > 0.$$

An investor would be willing to invest if $EU_{FD} \geq (1-\tau)y$ if expenses are fully deductible or $EU_{PD} \geq (1-\tau)y$ if expenses are partially deductible. Due to concavity of the utility function and Jensen's Inequality, it is easy to see that some housing investment may be profitable from a social perspective (in that expected rental income exceeds expenses) but a risk averse investor will not invest due to risk.

B.2 Capital gains discount and the incentive to invest

Here, we detail how a discount on capital gains taxation alters the incentive to invest in housing. Assume that housing investment is financed by debt (so $\eta = 1$) with an associated interest rate of r_b. The return on housing is now decomposed into a rental income, R_{rent} and a capital gain, R_{cg}.

In the absence of taxation, investing in housing will lead to the following payoff:

$$R_{rent} + R_{cg} - pr_b$$

and housing investment will be profitable if the rate of return on housing, $(R_{rent} + R_{cg})/p$ exceeds the interest rate on debt. Introducing taxes at the rate of τ, without a discount on capital gains, the payoff of investing in housing under a system of full deductibility of interest expenses is

$$(1-\tau)(R_{rent} + R_{cg} - pr_b)$$

and the investment is still pursued as long as $(R_{rent} + R_{cg})/p > r_b$. However, when capital gains are taxed at a discount the payoff to investing is

$$(1-\tau)(R_{rent} - pr_b) + \left(1 - \frac{\tau}{2}\right) R_{cg}.$$

and investments will be profitable to the investor if

$$\frac{\left(R_{rent} + \frac{1-\frac{\tau}{2}}{1-\tau} R_{cg}\right)}{p} > r_b$$

implying that the capital gains discount will encourage investment in housing, relative to a setting without taxation.

B.3 Definition of Stationary Equilibrium

Recall, the state vector of a household is defined as $x \equiv (a, z, \omega, s_{-1}, h_{-1})$, which reflects the household's age, earnings, housing depreciation rate, financial assets and housing stock. Here $a \in A = \{1, ..., A\}$, $z \in Z = \{z_1, ..., z_J\}$, $\omega \in \Omega$, $s_{-1} \in \mathcal{S} \subset \mathbb{R}$, and $h_{-1} \in \mathcal{H} \subset \mathbb{R}_+$. The individual state space is given by $X = A \times Z \times \Omega \times \mathcal{S} \times \mathcal{H}$. A stationary equilibrium consists of the value function $V(x)$, household decision rules $c(x)$, $\tilde{h}(x)$, $h(x)$ and $s(x)$, housing price p and rent p^r, an aggregate housing stock $\overline{H}$, and a stationary distribution on X, μ, such that:

(i) Taking p and p^r as given, the value function $V(x)$, and decision rules $c(x)$, $\tilde{h}(x)$, $h(x)$ and $s(x)$ solve the dynamic programming problem (12) of a household with state x.

(ii) The aggregate housing stock satisfies (14) with $H = H_{-1} = \overline{H}$.

(iii) The housing and rental markets clear:

$$\int_X h(x) d\mu = \overline{H} \tag{B.1}$$

$$\int_X \left(h_{-1} - \tilde{h}(x)\right) d\mu = 0 \tag{B.2}$$

where Equation (B.2) is a simplified version of the rental market clearing condition

$$\int_{\{x \in X: h_{-1} > 0\}} \left(h_{-1} - \tilde{h}(x)\right) d\mu = \int_{\{x \in X: h_{-1} = 0\}} \tilde{h}(x) d\mu$$

(iv) The distribution μ is stationary and consistent with household behaviour.

B.4 Derivation of the expression for ex-ante *cev*

To derive the expression for ex-ante *cev* in Equation (15), note that the expected lifetime utility of a household in the baseline economy is given by

$$V(x) \equiv \mathbb{E}_0 \left\{ \sum_{a=1}^{A} \beta^{a-1} P_{1,a-1} \left[\kappa_{a-1} u(c_a, \tilde{h}_a) + (1 - \kappa_{a-1}) \nu(\mathrm{b}_{a-1}) \right] + \beta^{A-1} P_{1,A}\, \nu(\mathrm{b}_A) \right\},$$

where $P_{1,J} = \Pi_{j=1}^{J} \kappa_{j-1}$ is the probability of surviving to age J from age 1 (letting $\kappa_0 = 1$). Then the *cev* required to equate the expected lifetime utility in the baseline economy to that in the counterfactual economy satisfies

$$\mathbb{E}_0 \left\{ \sum_{a=1}^{A} \beta^{a-1} P_{1,a-1} \left[\kappa_{a-1} u((1 + cev) c_a, (1 + cev) \tilde{h}_a) + (1 - \kappa_{a-1}) \nu((1 + cev) \mathrm{b}_{a-1}) \right] \right.$$
$$\left. + \beta^{A-1} P_{1,A}\, \nu((1 + cev) \mathrm{b}_A) \right\} = V^{cf}(x).$$

Using the functional forms of u and v in (1) and (2), the equation above simplifies to

$$(1+cev)^{1-\sigma}V(x) = V^{cf}(x),$$

which then gives the expression for $cev(x)$ in (15).

B.5 Calculation of insurance premium

We describe the calculation of the insurance premium for housing risk for the baseline economy. The process for calculating the housing insurance premium for a counterfactual economy and for calculating the income insurance premium is analogous. In the baseline economy, the value function for a newborn household entering the economy with zero assets and initial income z is given by $V(x)$, where $x = (1, z, 0, 0, 0)$. We then solve for the value function of a newborn in an identical economy, except that $\omega = 0$ in all periods so there are no shocks to housing. Define this value function as $V^{IP}(x)$ to reflect the value of a household that is insured against housing risk. The insurance premium a household in state x would be willing to pay, in cev units, is then determined as

$$(1 - cev_{IP}(x))^{1-\sigma}V^{IP}(x) = V(x)$$

which implies the household would be willing to reduce consumption in each period by $cev_{IP}(x)$ to eliminate the housing risk that is faced in the baseline economy. The derivation of the income insurance premium is analogous.

B.6 Price index as a measure for housing affordability

To think about the impact of changes in policy upon affordability we use the concept of a price index as represented by an expenditure function. For a renter, this expenditure function is:

$$e_r(p^r, u) = \min_{\{c,\tilde{h}\}}(c + p^r\tilde{h})$$

subject to $c^{\alpha}\tilde{h}^{1-\alpha} \geq u$ and $\tilde{h} \geq h_{min,rent}$. For a homeowner, the corresponding expenditure function is:

$$e_h(p, u) = \min_{\{c,\tilde{h}\}}(c + p^o\tilde{h})$$

subject to $c^{\alpha}(\lambda\tilde{h})^{1-\alpha} \geq u$ and $\tilde{h} \geq h_{min}$. Here, the price of owner-occupied housing is determined by the user cost of housing defined as $p^0 = p(\eta(r + m + \bar{\delta}) + (1-\eta)((1-\tau)r + \bar{\delta})$, where η represents the share of housing financed by debt and τ is the average tax rate (total

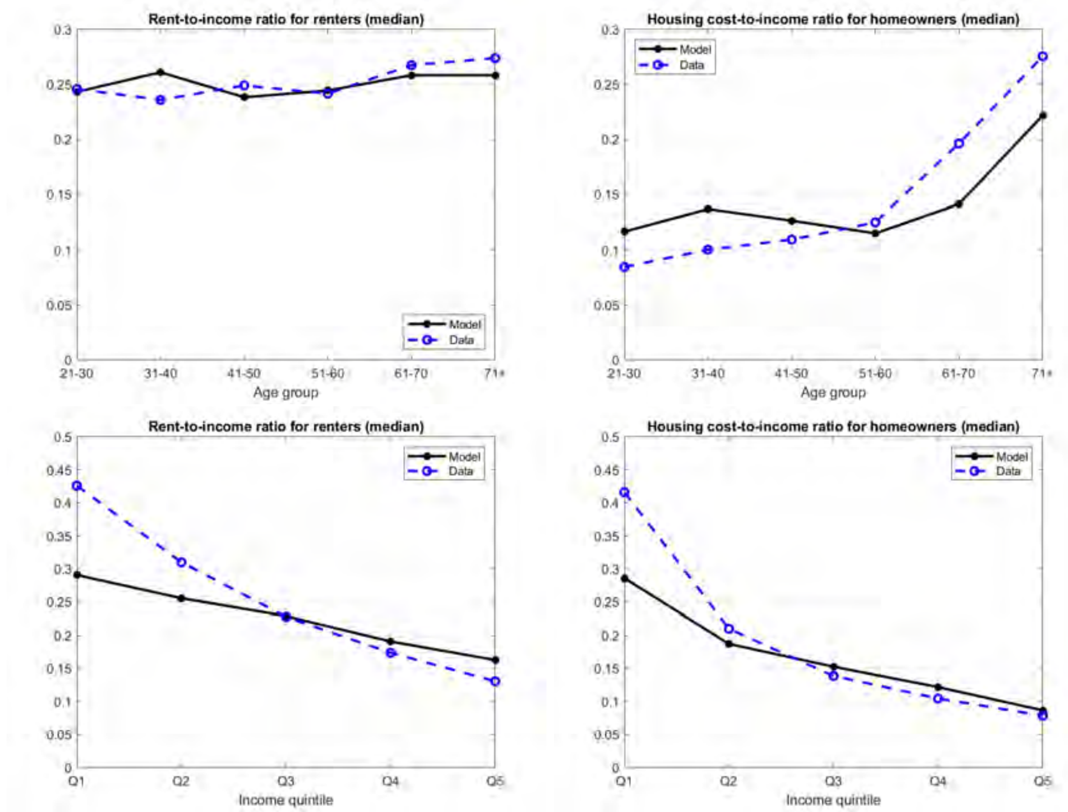

Figure C–1: Housing cost for renters and homeowners by age group and income quintile

Notes: The housing cost for homeowners is given by the sum of mortgage interest payment and depreciation expense in a given period. Data values are from SIH 2013-14.

tax relative to taxable income) paid by the homeowner. We assume that imputed rental income associated with equity financing is tax free. Note that the price of housing varies across owners: effective interest rates are affected by whether they use debt or equity finance and the tax benefits of imputed rental income vary with marginal income tax rates.

C Additional Quantitative Results

C.1 Additional quantitative properties of the baseline economy

Distribution of housing cost. Figure C–1 depicts the housing cost-to-income ratio for renters and homeowners by age and income. For renters, the housing cost is simply the rental expenditure. The housing cost for homeowners is defined as the sum of mortgage interest payment and depreciation expense on owner-occupied housing in a given period.[41] As displayed in the top panel, the housing cost in the model matches the data across the

[41] In SIH, we can obtain information on mortgage interest payments on a household's primary dwelling. However, we impute the depreciation cost using a depreciation rate of 2.5% per annum (Harding et al., 2007). In the model, we also use this average depreciation rate when calculating the depreciation expenses.

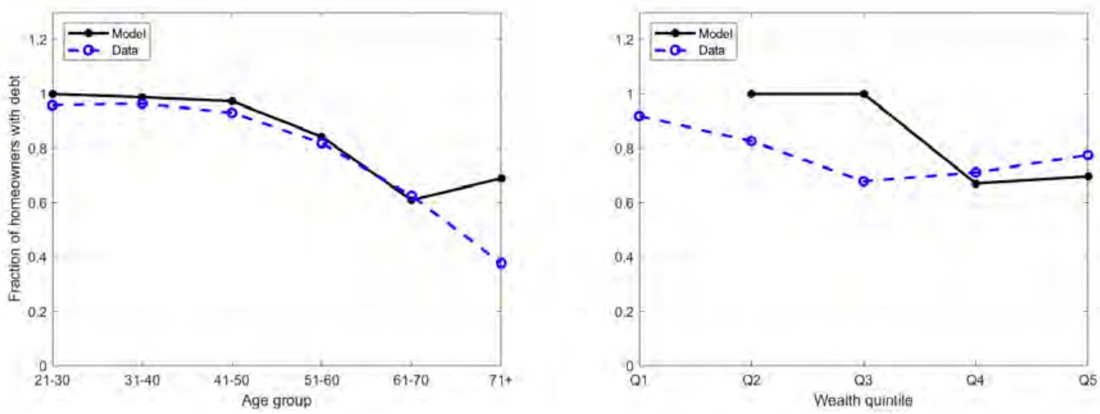

Figure C–2: Fraction of homeowners with debt

Data source: SIH 2013-14

age groups. The left panel shows that the age profile of the median rent-to-income ratio is relatively flat, with a value of around 0.25. This pattern comes from the fact that housing consumption and income of renters tend to decline with age, both in the model and in the data. In contrast, the right panel shows that housing cost-to-income ratio for homeowners tends to increase with age. This is because housing consumption of homeowners tend to increase with age, while income of homeowners displays a hump shape. The particularly high ratios for old homeowners result from the low income of these households. In the bottom panel, we plot these ratios by income quintile. The model is successful in generating the declining trend of the ratios with income, although it underestimates these ratios for lower income households.

Proportion of homeowners with debt. Figure C–2 compares the fraction of homeowners with debt in the model to the data. The left and right panels depict the fraction across the age groups and wealth quintiles, respectively. As in the data, the model produces a downward trend in the fraction of homeowners with debt over the life-cycle although it diverges from the data value for the oldest age group. Across the wealth quintiles, the model tends to overestimate the fraction of homeowners with debt for lower wealth quintiles.[42]

Average net rental income. Figure C–3 compares the average net rental income in the model to the data, by age (left panel) and by income quintiles (right panel). The model captures the upward trend in average net rental income with age and the downward trend with income. The model misses the average net rental income for the elderly. This is also reflected in the left panel of Figure 6 with the model over-estimating negatively geared landlords over the age of 71.

[42]There are no homeowners in the first wealth quintile in the model, so there is a missing value for this quintile.

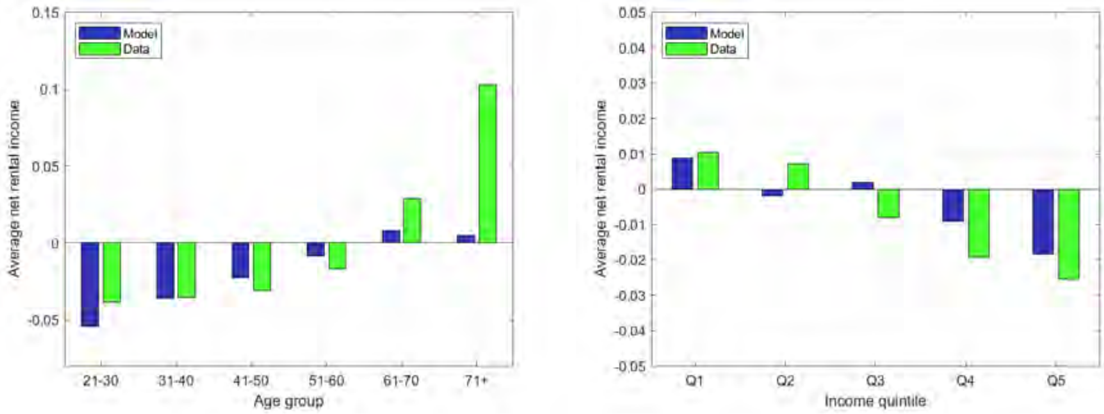

Figure C–3: Average net rental income by age and income

Notes: Net rental incomes are normalised by the median annual household income. Data values are from the ALife Database.

C.2 Steady state comparison of home ownership and landlord rates

Figure C–4 depicts the home ownership and landlord rates by age and by wealth quintiles. One point we would like to highlight is that in the rental assistance case, the landlord rate for households in the highest wealth quantile is higher than in the baseline. This explains why the total investment housing stock increases in the rental assistance case despite a fall in the overall landlord rate; wealthy landlords tend to invest more in housing than less wealthy ones.

C.3 Steady state comparison of housing cost

Table C–1: Percentage change in rent-to-income ratio and rental housing size

	Lump-sum transfer		**Rental assistance**	
	% Δ in		% Δ in	
Income percentile	Rent-to-income	Housing size	Rent-to-income	Housing size
Bottom 5%	0.529	0.000	-3.479	0.000
5-25%	1.287	-0.339	0.642	0.056
25-75%	-2.291	-3.874	0.213	-1.835
75- 95%	-3.590	-5.659	-0.696	-3.905
Top 5%	0.944	-1.586	0.946	-3.213

Here, we consider the rent-to-income ratio for renters and the housing cost-to-income ratio for homeowners as an alternative measure of housing affordability, and compare these ratios in the baseline and counterfactual steady states. The idea is that if removing negative gearing helps improve housing affordability, these ratios may decrease in the counterfactual steady states. However, this measure is confounded with endogenous changes in housing

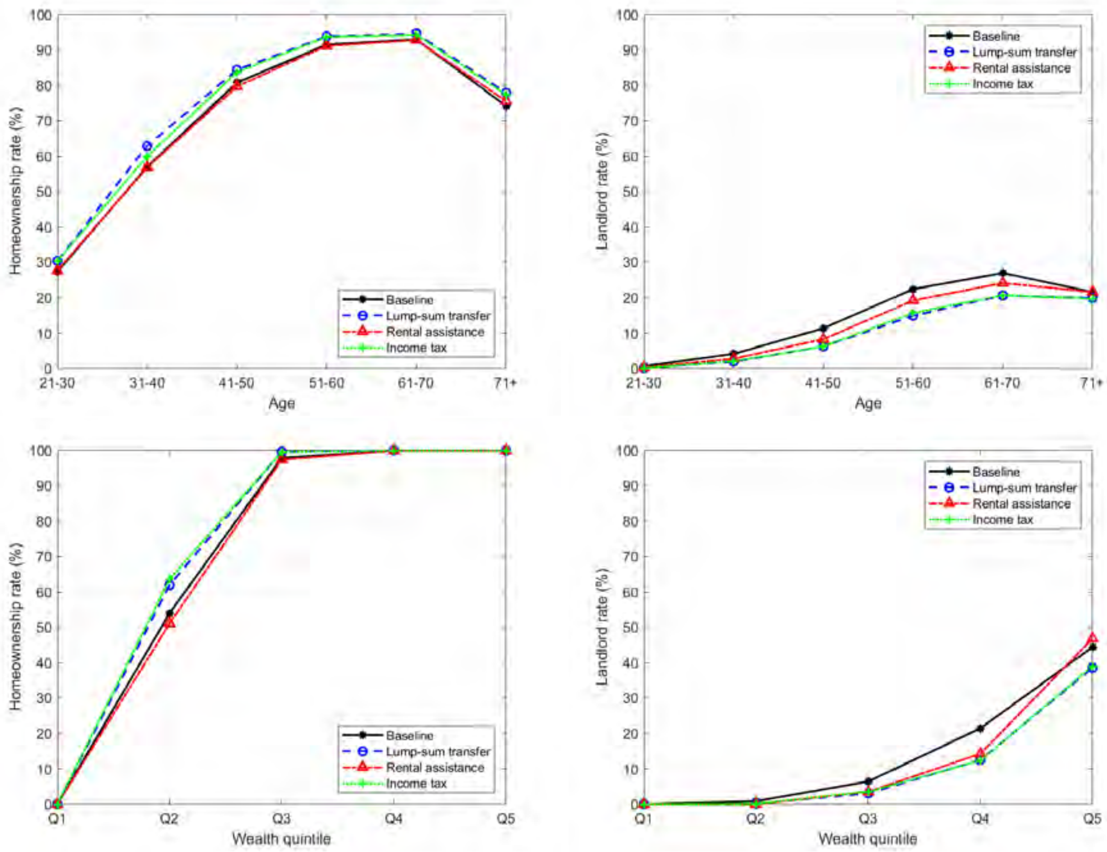

Figure C–4: Home ownership and landlord rates by age and wealth

Table C–2: Percentage change in housing cost-to-income ratio and owner-occupied housing size

	Lump-sum transfer		Rental assistance	
	% Δ in		% Δ in	
Income percentile	Housing cost-to-income	Housing size	Housing cost-to-income	Housing size
Bottom 5%	-3.302	-0.383	-0.903	-0.381
5-25%	-1.273	0.178	-0.273	-0.051
25-75%	-0.724	0.249	0.066	0.136
75- 95%	-0.211	0.468	0.316	0.294
Top 5%	-0.911	0.013	-0.435	-0.249

sizes; lower levels of housing services in the counterfactual economy could also reduce this ratio. A comparison without holding household utility fixed can be misleading.

Table C–1 reports the percentage changes in the rent-to-income ratios for renters from their baseline levels in the lump-sum transfer and rental assistance experiments, and Table C–2 reports the percentage changes in housing cost-to-income ratios for homeowners. The corresponding percentage changes in rental housing and owner-occupied housing are also reported.[43] We highlight a few observations. First, in both experiments, the average rental housing size decreases for almost all renters (except the poorest renters due to the minimum rental size restriction), driven by the rise in rental price. However, the rent-to-income ratio either increases or decreases by a smaller percentage than the drop in rental housing size. The only exception is for the poorest renter group in the rental assistance economy; their average rent-to-income ratio falls by 3.5%. These results seem to suggest that the removal of negative gearing worsens housing affordability for renters except for poorest renters in the rental assistance case. In contrast, the housing cost-to-income ratio decreases for all homeowners in the lump-sum transfer experiment, although the size of owner-occupied housing tends to increase. This result seems to suggest an improvement in housing affordability for homeowners. The results are less clear in the rental assistance case, although there seems to be an improvement in housing affordability for lower-income homeowners.

C.4 Steady state results under different policy experiments

In this subsection, we present the steady state results for three additional policy experiments: 1) partial (50%) removal of negative gearing; 2) full removal of negative gearing with 25% capital gains tax discount; 3) maintaining negative gearing but removing capital gains tax discount.[44] In these experiments, additional tax revenue is distributed as a lump-sum transfer to all households. Table C–3 reports selected steady state results for these experiments.

[43]As for the price index calculation, these results are based on a matched sample of households with the same states across the baseline and counterfactual steady states.

[44]The second experiment resembles the reform of negative gearing proposed by the Australian Labor Party in the 2016 and 2019 election.

Table C–3: Alternative policy experiments

	Baseline	Counterfactual		
		Experiment 1	Experiment 2	Experiment 3
Price	3.139	3.124	3.117	3.136
Rent	0.538	0.543	0.557	0.545
Price-rent ratio (annual)	11.67	11.50	11.20	11.52
Overall home ownership rate	0.697	0.712	0.715	0.703
Home ownership for under 35	0.334	0.334	0.365	0.337
Landlord rate	0.145	0.123	0.111	0.151
Frac. of NG landlords	0.525	0.430	0.362	0.524
Total housing supply (normalized)	1	0.991	0.986	0.998
Share of rental housing (%)	16.5	15.4	14.5	16.7
Total tax revenue (normalized)	1	1.006	1.011	1.000
Avg. tax paid by landlords	0.269	0.273	0.274	0.261
Transfer	-	0.002	0.003	0.000
Ex-ante *cev* (%)	-	0.19	-0.12	-0.30

Notes: Experiment 1 refers to a counterfactual policy experiment where negative gearing is partially removed (by 50%). Experiment 2 is an experiment where negatively gearing is fully removed and capital gains discount is reduced to 25%. Experiment 3 is an experiment where negative gearing is maintained but capital gains tax discount is removed.

Partial removal of negative gearing. The third column of Table C–3 reports the results when landlords can only deduct 50% of their net rental income losses from their taxable income. We find that the directions of the effects on the steady state house price, rent, and other moments are the same as those in the lump-sum transfer experiment, although the size of the effects is smaller. Notably, the partial removal of negative gearing delivers a higher steady state welfare gain; the mean *cev* of newborn households is 0.19%, as compared to 0.13% in the lump-sum transfer experiment when negative gearing is fully removed. Newborns experience a higher welfare gain because the rise in rent, driven by the fall in rental supply, is weaker with the partial removal of negative gearing. Therefore, the negative welfare effects arising from the higher steady state rent is smaller.

Full removal of negative gearing with 25% capital gains tax discount. The fourth column of Table C–3 reports the results when negative gearing is fully removed and the capital gains tax discount is reduced from 50% to 25%. Qualitatively, this experiment generates a similar set of results as the lump-sum transfer experiment where the house price declines, rent increases, and the home ownership rate increases. However, we observe that there is a steady state welfare loss of -0.12%. The full removal of negative gearing combined with a further reduction in the capital gains tax discount compresses the rental supply and increase the rent relatively more. This makes newborn households who enters the economy as renters worse off.

Negative gearing without capital gains tax discount. In the fifth column of Table C–3, we present the results for an experiment where we allow landlords to fully deduct their net rental losses from their taxable income, but completely remove the capital gains tax discount. Unlike other experiments, we do not find a significant drop in the house price while the rent rises. The moments related to landlords such as the landlord rate and the fraction of negative geared landlords remain at similar levels as in the baseline economy. Furthermore, the government collects almost an equal amount of tax revenue. In terms of welfare, newborn households would experience a welfare loss of 0.30%. In this economy, they pay a higher rent, face a similar purchase price of housing, but do not receive a lump-sum transfer.

C.5 Welfare effects over transition: by initial income, wealth and mortgage status

Here we discuss the welfare effects of removing negative gearing on existing households by their initial income, wealth, and mortgage status. These results are presented in Table C–4. In the lump-sum transfer experiment, households in the third and fourth income quintiles and the second and third wealth quintiles experience slightly larger welfare gains than other groups. We also note that households in the lowest wealth quintile, who are likely to be renters, suffer from a welfare loss due to the rise in rent. The welfare effects are more heterogeneous in the rental assistance experiment where the size of welfare gain decreases with household income and wealth. Compared with the lump-sum transfer case, there are much larger welfare gains for households in the bottom two income and wealth quintiles, as a majority of these households are renters and hence receives a transfer that is larger than in the lump-sum transfer case. The policy reform negatively impacts households in the top income quintile and the fourth wealth quintile, as many of these households are more likely to be negatively geared landlords.

The average welfare gain for homeowners with initial mortgage is smaller than for homeowners without a mortgage in the lump-sum transfer case, but this comparison is reversed in the rental assistance case. Homeowners with a mortgage are more likely to be landlords. In the lump-sum transfer case, they benefit less from the removal of negative gearing than homeowners without a mortgage who are more likely to be owner-occupiers. However, in the rental assistance case, they benefit more from a larger increase in the rent compared with homeowners without a mortgage.

Table C–4: Welfare over transition: by initial income, wealth quintiles, and mortgage status

	Lump-sum transfer			Rental assistance		
	Mean (%)	Median (%)	$P(cev_i > 0)$	Mean (%)	Median (%)	$P(cev_i > 0)$
Income quintile						
Q1	0.176	0.145	0.641	1.074	0.787	0.768
Q2	0.152	0.112	0.615	0.441	0.357	0.750
Q3	0.208	0.251	0.726	0.230	0.167	0.709
Q4	0.215	0.282	0.795	0.049	0.055	0.635
Q5	0.109	0.159	0.763	-0.025	-0.023	0.435
Wealth quintile						
Q1	-0.008	-0.052	0.365	0.987	0.793	0.967
Q2	0.317	0.341	0.870	0.596	0.196	0.798
Q3	0.261	0.326	0.796	0.107	0.032	0.582
Q4	0.144	0.201	0.726	-0.080	-0.050	0.362
Q5	0.150	0.165	0.796	0.123	0.036	0.567
Initial homeowners						
Without mortgage	0.276	0.271	0.948	0.023	-0.078	0.468
With mortgage	0.219	0.274	0.781	0.107	0.044	0.576

D Robustness Checks

D.1 Steady state with different housing supply elasticities

Our baseline calibration uses a housing supply elasticity of $\varepsilon = 2$. For robustness, we examine the steady state results with $\varepsilon = 0$ (fixed housing supply) and $\varepsilon = 4.5$ (highly elastic supply). Results are reported in Table D–5.

The choice of ε mostly affects the house price. With more elastic housing supply ($\varepsilon = 4.5$), the house price falls by less relative to the $\varepsilon = 2$ case. Conversely, when the housing supply is inelastic ($\varepsilon = 0$), the fall in house price is larger. Examining welfare, we find that the steady state welfare gain is larger (smaller) for the inelastic (more elastic) case in both experiments. The intuition is that newborn households benefit from lower house prices, which makes it easier for them to become homeowners. When housing supply is more elastic, house price does not decline as much. The welfare gain is smaller because the decrease in house price is not as large such that it offsets the negative welfare effects coming from the rise in rent by a smaller amount. Another observation is that the steady state welfare comparison between the two experiments is robust to different ε values; the welfare gain remains much larger in the rental assistance case than in the lump-sum transfer case,

D.2 Steady state results without housing value shock

Here, we analyse a version of our model which does not feature the housing value shock. To do so, we re-calibrate the baseline model and run the same set of counterfactual experiments as in Section 6. We report the newly calibrated parameters and moments in Tables D–6 and D–7 and the steady state results in Table D–8. We make two observations. First, without the housing value shock, we are unable to match the fraction of negative geared

Table D–5: Steady state comparison: different housing supply elasticities

	Baseline	Counterfactual					
		Lump-sum transfer			Rental assistance		
		$\varepsilon = 0$	$\varepsilon = 2$	$\varepsilon = 4.5$	$\varepsilon = 0$	$\varepsilon = 2$	$\varepsilon = 4.5$
Price	3.139	3.108	3.110	3.122	3.085	3.128	3.134
Rent	0.538	0.553	0.551	0.554	0.553	0.560	0.561
Price-rent ratio (annual)	11.67	11.25	11.28	11.28	11.16	11.18	11.17
Overall home ownership rate	0.697	0.729	0.723	0.722	0.662	0.688	0.688
Home ownership for under 35	0.334	0.375	0.364	0.364	0.345	0.334	0.334
Landlord rate	0.145	0.112	0.107	0.106	0.133	0.128	0.126
Frac. of NG landlords	0.525	0.353	0.359	0.364	0.345	0.338	0.343
Total housing supply (normalized)	1	1	0.982	0.972	1	0.993	0.988
Share of rental housing (%)	16.5	15.3	14.3	14.3	18.5	17.9	17.5
Total tax revenue (normalized)	1	1.012	1.011	1.011	1.014	1.014	1.013
Avg. tax paid by landlords	0.269	0.298	0.274	0.278	0.307	0.289	0.301
Transfer/Rental assistance	-	0.003	0.003	0.003	0.011	0.011	0.011
Ex-ante *cev* (%)	-	0.18	0.13	0.02	1.69	1.45	1.42

Table D–6: Internally calibrated parameters (without housing value shock)

	Parameter	Value
λ	Utility premium for homeowners	1.04
h_{min}	Minimum housing size for owning	0.335
$h_{min,rent}$	Minimum housing size for renting	0.142
ϑ	Bequest intensity	10
β	Discount factor (2-year)	0.850
α	Share of non-durable consumption	0.680
ζ	Fixed cost of being a landlord	0.039
φ	Fraction of investment housing loans claimed	0.982
ψ_1	Scale parameter for housing production	4.636

Table D–7: Target moments for internal calibration (without housing value shock)

Target Moment	Model	Data	Source
Average home ownership rate	0.68	0.69	SIH 2013-14
Home ownership rate for under 35	0.39	0.37	SIH 2013-14
Home ownership rate for 65+	0.79	0.84	SIH 2013-14
Minimum rental expenditure	0.18	0.15	SIH 2013-14
Loan-to-value ratio (median)	0.51	0.49	SIH 2013-14
Rent-to-income ratio (median)	0.24	0.25	SIH 2013-14
Fraction of landlords	0.15	0.13	SIH 2013-14
Share of investment loan to total loan for landlords (median)	1.00	0.98	ALife
Ratio of interest to total expense on invest. housing (median)	0.61	0.50	ALife
Median house value	3.02	3.28	SIH 2013-14

Notes: The minimum rental expenditure and the median house value are both normalized by the annual median household income.

landlords. In the baseline economy, less than 27% of landlords are negatively geared, much lower than the data value of 59%. Second, removing negative gearing does not significantly change the steady state outcome. While the fraction of negatively geared landlords reduces to around 16%, the effects on the equilibrium objects and other moments such as the house price, rent, home ownership rate, housing supply, and the size of transfer payments are almost unchanged. To understand these results, we note that the average rental loss in this economy is only 20% of the average rental loss in an economy with shocks. Households are making losses, but only small losses. When the policy is removed, the additional revenue is small and there are only minor changes in welfare across different experiments.

Table D–8: Steady state without housing value shocks

	Baseline	**Counterfactual**		
		LS transfer	**Income tax**	**Rent. Assist.**
Price	3.266	3.267	3.268	3.269
Rent	0.522	0.520	0.520	0.521
Price-rent ratio (annual)	12.52	12.57	12.57	12.54
Average home ownership rate	0.685	0.684	0.684	0.684
Home ownership for under 35	0.386	0.386	0.386	0.386
Landlord rate	0.150	0.134	0.133	0.138
Frac. of NG landlords	0.266	0.164	0.166	0.155
Total housing supply (normalized)	1	1.002	1.002	1.003
Share of rental housing (%)	0.183	0.177	0.176	0.184
Total tax revenue (normalized)	1	1.001	1.001	1.001
Avg. tax paid by a landlord	0.304	0.310	0.315	0.315
Transfer/Rental assistance	-	0.000	-	0.001
Ex-ante *cev* (%)	-	0.15	0.01	0.19

E Computational Details

State and choice variables. A household's current state vector consists of savings (risk-free asset holding) s_{-1} and housing asset h_{-1} acquired in previous period, the realizations of income shock z and depreciation shock (if $h_{-1} > 0$), and age a in current period. The choice variables include savings s, housing asset h, housing services $\tilde{h}$, and non-durable consumption c. The state spaces for owner-occupied and rental housing are as described in the text. The state space for savings is discretized into 66 grids. Households are allowed to choose the maximum possible borrowing for each owner-occupied housing size, $s = -(1-\theta)ph$. We define each of these points as knots. Between a pair of knots, we allow for three equally spaced grids so that it gives more flexibility in choosing the size of mortgages. The savings grid is more finely spaced for lower levels of borrowings. For positive values of 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.

Computation of stationary equilibrium. The stationary equilibrium for the baseline economy is computed using constant house price p and rent p^r. We start first by guessing those two equilibrium objects. Given p and p^r, we compute the optimal policy and value functions for the last period, $A = 32$. We then solve the household problem for all other periods using backward induction. Once we obtain policy functions, we simulate the economy until a stationary distribution of households over the state space is achieved. To do so, we draw 20,000 households who enter the economy as newborns with zero savings and housing stock. At the beginning of each period, households draw age-dependent death shocks. If a household survives, they draws a current income shock (from the distribution of the Markov chain conditional on their income shock in previous period) and depreciation shock on existing housing stock and makes decisions on consumption and housing services in current period and savings and housing stock to be taken to next period. If a household dies, they are replaced by a newborn household who then draws initial income stock from the stationary distribution of the income shock and make decisions on consumption, housing services, savings and housing stock. We simulate the optimal behaviour of the households forward using the computed policy functions. Households exit the economy with certainty after 32 periods. The stationary distribution is obtained when the age distribution, average income, average savings, and average housing stock across the 20,000 households are all stabilized. Using the stationary distribution, we check whether the housing market and rental market clear and update p and p^r accordingly. The procedure described above is repeated until the equilibrium house price and rent are found.

For the counterfactual economies, the stationary equilibria are computed in a similar way, but we have one more equilibrium object to pin down. For example, we need to determine the equilibrium amount of the lump-sum transfer in the lump-sum transfer experiment. This is determined by equating the steady state net tax revenue (tax revenue minus transfer payment) in the counterfactual economy to the tax revenue in the baseline economy. In the computation, we iterate on the lump-sum transfer, together with house price and rent.

Internal calibration. For a given set of candidate values for the internally calibrated parameters, the stationary equilibrium of the model is solved and simulated as described above. The targeted moments are then computed using the simulated households data in the stationary distribution, and compared with the corresponding data moments. The parameter values are updated and this procedure is repeated until the model moments are close to the data moments.

Computation of transition dynamics. We describe the algorithm for computing the transition dynamics for the lump-sum transfer experiment. The computation for the rental assistance case is similar. Define a vector $w_t \equiv [p_t, p_t^r, F_t]$ and let μ_t denote the distribution of households over age, income shock, depreciation shock, savings and housing stock in each transition period t. The baseline steady state is when $t = 0$ and the new steady state for the counterfactual economy corresponds to $t = T$. The task is to find the transition paths of w_t that clear the housing and rental markets and maintains revenue neutrality in each transition period. With outcomes from the stationary equilibria, we know the starting point w_0 and μ_0, and the end point w_T and μ_T, of the transition paths. The algorithm involves the following steps.

1. Choose the length of transition phase, T. Choosing a large number increases the computational burden. We set $T = 12$, i.e., the transition to the new steady state completes within 24 years.

2. Guess a sequence of w_t for $t = 1, ..., T - 1$.

3. Given the guessed sequence of w_t, solve backward for the value function V_t (taking as given V_{t+1}), starting from $T - 1$. Note that V_T is the steady state value function for the counterfactual economy, which is known.

4. Given the value functions $V_t, t = 1, \ldots, T$, find the market clearing prices and revenue-neutral transfer for each period $t = 1, \ldots, T - 1$, starting from period 1. For each period, the computation follows the procedure described earlier for computing the market clearing prices in a stationary equilibrium. The revenue-neutral transfer is obtained by equating the net tax revenue of the government (i.e., tax revenue minus transfer) to the tax revenue that would be obtained in the absence of the policy reform in each transition period. This gives a sequence of $\hat{w}_t$ and corresponding distribution $\hat{\mu}_t$ for each transition period $t = 1, ..., T - 1$.

5. Compare $\{\hat{w}_t\}$ and $\{w_t\}$. If they are different go back to Step 2 to update the guessed price sequence and repeat Step 3 and 4 until convergence is achieved.

6. Calculate the distribution in period T, $\hat{\mu}_T$, and compare it with the stationary distribution in the counterfactual economy. Increase T if the two distributions differ.

We find that for the lump-sum transfer experiment, $T = 12$ is enough. However, the transition takes longer for the rental assistance experiment, with $T = 24$.

F Estimation of the Income Process

In this section of the Appendix, we provide the empirical estimates of income process using the HILDA survey which we use to calibrate the household earnings dynamics in our model.

For the income variable we use the gross income reported at the household level. In HILDA, the gross income captures income sources from labour, 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 labour income;
4. Full-time working households; and
5. 10 consecutive years of appearance.

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

Model specification. The specification of labour income for household 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 households' 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 households 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.

$$\log Y_{i,a,t} = \beta' X_{i,a,t} + \hat{y}_{iat} \tag{F.1}$$

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 $\hat{y}_{i,a,t}$ summarises 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.

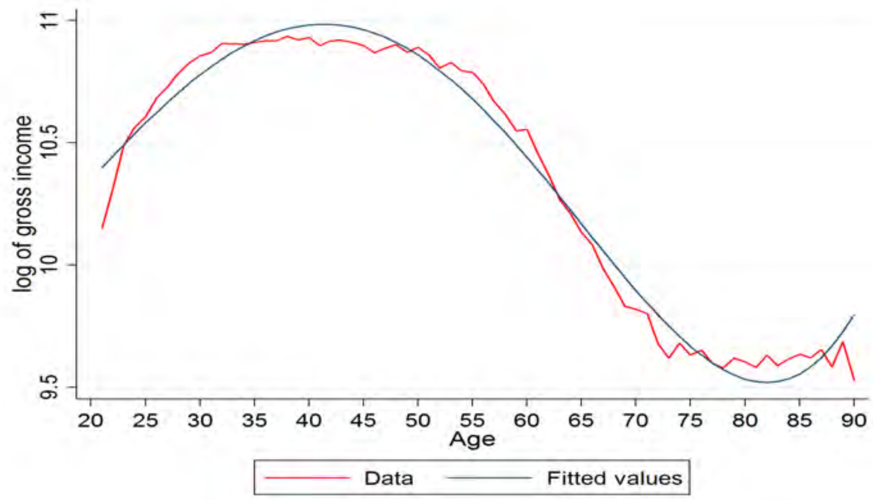

Figure F–5: Deterministic component

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

$$\hat{y}_{i,a} = z_{i,a} + \varepsilon_{i,a} \tag{F.2}$$

$$z_{i,a} = \rho z_{i,a-1} + u_{i,a} \tag{F.3}$$

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 Heathcote, Perri and Violante (2010) and Tonetti (2011). 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 households in the panel is large. In our baseline sample, there are 1,592 households.

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

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

where $d_{i,a} \in \{0, 1\}$ is an indicator variable for whether household 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

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

Table F–9: Estimates of income process using HILDA

	10 consecutive	5 consecutive
ρ	0.941	0.956
σ_u^2	0.030	0.026
$\sigma_{z,0}^2$	0.138	0.169
σ_ε^2	0.081	0.141
No. of households	1,541	3,341

Note: The model is estimated using the minimum distance method.

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 vectorise 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

$$\min_{\theta} \left[\widehat{\mathbf{M}} - \mathbf{M}(\theta)\right]' \Omega \left[\widehat{\mathbf{M}} - \mathbf{M}(\theta)\right] \tag{F.4}$$

where Ω is a weighting matrix.

Result. In the second column of Table F–9, 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 F–9 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 two years.[45] Here, we introduce a simulation technique

[45] 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.

Table F–10: Estimates of income process using simulated data

	Actual	1 year	2 year	3 year	4 year	5 year
ρ	0.941	0.920	0.837	0.768	0.726	0.640
σ_u^2	0.030	0.043	0.103	0.153	0.195	0.236
$\sigma_{z,0}^2$	0.138	0.219	0.178	0.134	0.064	0.000
σ_ε^2	0.081	0.037	0.000	0.000	0.000	0.004
No. of households	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.

that enables us to approximate earnings process parameters with any model periods.

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 households, entering the model economy at the age of 21. Also we assume that $z_{i,0} = 0$
2. For each household 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 household with a new household entering the model with age 21. The new household starts their life-cycle from this period, as noted in (a) and (b).
3. Continue this process for 120 periods. It gives us an unbalanced panel consists of 600,000 observations and 20,521 households exiting the panel at different ages.

After obtaining the large panel of income data, we can perform the MDE for any model period. The estimates for 2, 3, 4, and 5 years are reported in Table F–10. In particular, for the two-year income process, the persistence and variance of shocks are given by 0.837 and 0.103, respectively. The calibration of the income process in our baseline model are based on these estimates. Table F–10 shows that the estimates of 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 in the third column. Encouragingly, the key parameters, ρ and σ_u^2 are close to the actual estimates reported in the second column of Table F–10, reinforcing the credibility of our simulation procedure.