Declining Interest Rates and Homeownership in Australia

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PRELIMINARY AND INCOMPLETE

Abstract

In this paper we study the effects of the decades-long decline in real interest rates on homeownership in Australia. We build a heterogeneous-agent life-cycle model with housing market equilibrium, calibrated to capture the cross-sectional patterns of Australian homeownership. We model the decline in interest rates between 1995 and 2019 as a sequence of unexpected shocks. The model generates a rise in house prices that is in line with the data. Additionally, the shocks explain nearly all of the observed changes in homeownership across the age spectrum. We find that around 25 percent of the fall in young homeownership rates is due to higher mortgage down-payments, and a further 25 percent is due to rising tax costs associated with purchasing a home.

Keywords: Housing, homeownership, house prices, interest rates, credit constraints, stamp duty

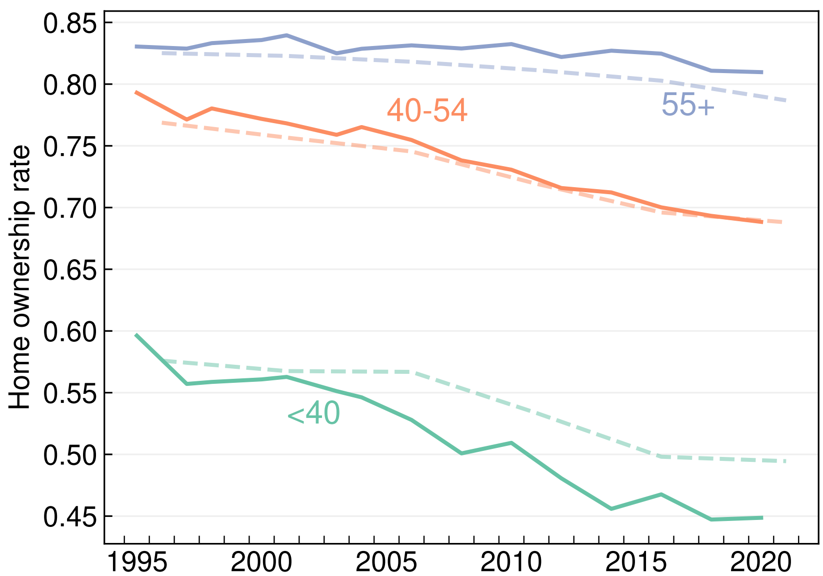
JEL classification: D15, E43, G51 ,R21

Yadav and Cusbert: Reserve Bank of Australia. Graham: University of Sydney. The views expressed in this paper are those of the authors and should not be attributed to the Reserve Bank of Australia. Any errors are the sole responsibility of the authors.

1. Introduction

Housing affordability in Australia has deteriorated substantially in recent decades, with a growing number of Australians finding it increasingly difficult to enter the housing market. Of particular concern has been the marked decline in homeownership rates among younger households. For Australians under the age of 40, homeownership has fallen by 10 to 15 percentage points (Figure 1). These trends in homeownership coincide with two significant shifts in macroeconomic conditions: a sustained decline in real interest rates (Figure 2(a)) and a sharp rise in house prices, which have outpaced household income growth (Figure 2(b)). In this paper, we examine the impact of these long-run macroeconomic changes on housing affordability and homeownership in the Australian housing market.

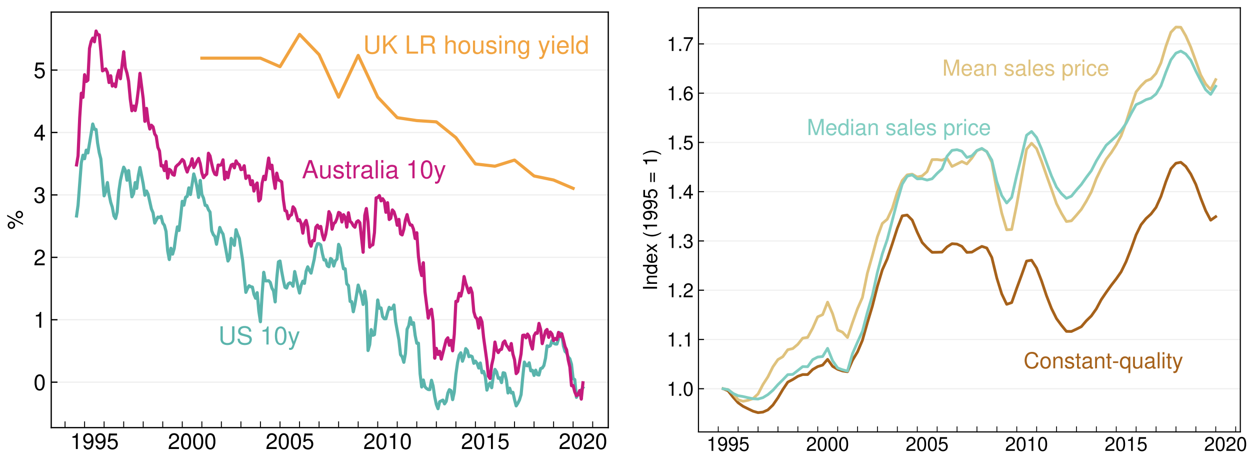
Figure 1: Homeownership Rates by Age Group



Notes: Solid lines are data from the 1994/5–2019/20 waves of the Survey of Income and Housing. Dashed lines are from the five-yearly Censuses between 1996–2021.
Source: ABS

The Australian housing market is particularly interesting both because of its exceptionally high housing costs by international standards and its distinctive institutional settings. The average house price-to-income ratio is around 5.5, placing Australian housing among the most expensive in the world (Reserve Bank of Australia 2024). As a result, the Australian housing market is outsized, with a total value of approximately four times annual GDP. Homebuyers in Australia face progressive stamp duty taxes on property purchases, while loan-to-value and payment-to-income requirements constrain mortgage borrowing. These features suggest that even modest changes in interest rates or house prices may translate into large effects on housing affordability and homeownership.

Figure 2: Real Yields and House Price-Income Ratios, 1995–2019



A. Real Yields **B.** House Price-Income Ratios

Sources: ABS; Bäcker-Peral, Hazell and Mian (2023); CoreLogic; Hambur and Finlay (2018); D'Amico, Kim and Wei (2018).

In this paper, we provide the first quantitative assessment of the long-run dynamics between interest rates, house prices, and homeownership in Australia. We develop a heterogeneous-agent life-cycle model that incorporates detailed housing tenure choices and mortgage finance decisions. The model is calibrated to match key features of the Australian housing market as it stood in 1995, a period when housing was more affordable and homeownership rates were relatively high across all age groups. Using this model, we simulate the effects of a sequence of unexpected declines in real interest rates from 1995 through 2019. In our dynamic equilibrium, both rents and house prices adjust each period. The model successfully replicates observed long-term trends in price-to-income and rent-to-income ratios, as well as homeownership rates across different age and income groups. We find that around 25 percent of the decline in young homeownership rates is attributable to larger required mortgage down payments, while another 25 percent is due to rising transaction costs associated with purchasing a home.

Our modeling approach follows the recent macro-housing literature, which uses heterogeneous agent models to study the effects of macroeconomic shocks and policy changes on the housing market (e.g. Chambers, Garriga and Schlagenhauf (2009), Kaplan, Mitman and Violante (2020), Kinnerud (2024) to name a few). As in this literature, our model features housing decisions made over the household life cycle and accounts for significant inequality in income, savings, access to housing, and debt. In the model, young households start with relatively low incomes and little wealth, requiring them to rent while they save for a housing downpayment. These savings are then combined with mortgage finance to purchase a first home. However, mortgage borrowing is constrained by maximum loan-to-value (LTV) and payment-to-income (PTI) limits.[1] Given the high average house prices in Australia, these borrowing constraints make first-time homeownership difficult without both substantial savings and a sufficiently high income to meet repayment obligations. Our model also incorporates progressive housing purchase taxes, known in Australia as stamp duty. As house prices rise these transaction costs grow even more quickly as buyers move up the stamp duty schedule. Thus, this mechanism amplifies the effects of rising house prices, presenting an additional barrier to homeownership.

We employ standard calibration techniques to ensure the baseline model captures key features of the Australian housing market in 1995. We target observed statistics on mortgage LTV ratios, house price-to-income ratios, and homeownership rates, particularly among young and low-income households. The model successfully reproduces the significantly higher homeownership rate in 1995 compared to today, as well as the substantially lower levels of house prices and mortgage debt. Additionally, the model replicates life-cycle profiles of homeownership, gross housing wealth-to-income ratios, and mortgage LTV ratios among homeowners.

We then use the model to study the effects of long-run changes in interest rates on housing affordability and homeownership. To do this, we subject the model to a sequence of unexpected and permanent interest rate shocks that mimic the observed decline in interest rates between 1995 and 2019. We make two key assumptions about household beliefs in response to these shocks. First, households do not anticipate the path of interest rate declines; instead, they are surprised each year as interest rates drop further. Second, households are myopic in their understanding of housing market equilibrium, believing that the current market clearing house prices and rents will persist indefinitely. The first assumption aligns with historical data from bond markets and survey expectations, while the second simplifies the computation of transitional dynamics by allowing us to solve for equilibrium in each period independently.

A critical parameter governing the model's equilibrium dynamics is the price elasticity of housing supply. High elasticities of supply imply that increases in housing demand lead to large increases in housing stock, moderate price changes, and minimal impact on homeownership. In contrast, low supply elasticities lead to sharp house price increases and larger changes in homeownership. Given the uncertainty surrounding the true value of

[1] See Greenwald (2018) for a discussion of PTI ratios in the American housing market. Recent work by Graham (2024) and Graham and Sharma (2024) models net income surplus ratio constraints, which are often imposed on borrowers by Australian banks.

this parameter, we explore scenarios with both low and moderate elasticities, as estimated in the literature for Australia. Supply elasticity estimates for Australia vary widely, from 0.07 Saunders and Tulip (2019) to 0.4 Gitelman and Otto (2012).

Following the sequence of unexpected interest rate shocks, the model generates responses in house prices, rents, and homeownership that closely track the long-run trends observed between 1995 and 2019. The house price-to-income ratio increases by around 40 percent over this period, in line with the data, while the rent-to-income ratio decreases by about 20 percent, again consistent with the data. Importantly, our assumptions that each interest rate shock is a surprise and that households are myopic about equilibrium dynamics result in a gradual movements in these prices over time, matching observed patterns. This contrasts sharply with the perfect foresight experiments, where house prices significantly overshoot their long-run equilibrium in the short run. As in the data, homeownership rates among households under 40 decline from 60 percent to approximately 45 percent, and the rate for households aged 40 to 55 falls from 78 percent to 70 percent.

Our experiments suggest that the rise in house prices caused by lower interest rates can explain approximately 90 percent of the observed decline in homeownership rates across the household age distribution. In a series of decomposition exercises, we identify two primary mechanisms driving this outcome. First, rising house prices lead to a tightening of mortgage credit constraints due to the increased down payment requirement. Second, higher transaction costs, particularly progressive stamp duties, make purchasing a home significantly more expensive. Notably, due to rising house prices and bracket creep, the effective average stamp duty rate increases from 2.6 percent in 1995 to 3.6 percent in 2019. Together, these two channels explain about half of the decline in homeownership rates for households under 40. The remaining decline is driven by other factors, such as the low responsiveness of housing supply and shifts in rental demand influenced by changing rental rates.

1.1. Related Literature

We follow a growing literature using structural macroeconomic models with inequality to study housing markets. These papers typically build and calibrate heterogeneous agent life-cycle models with household decisions over renting, owning, and mortgage finance. The models are then used to study the effects of various macroeconomic and policy changes on housing market outcomes. Greenwald (2018) studies the influence of PTI borrowing constraints on the transmission of transitory interest rate shocks through the housing market. Kaplan *et al* (2020), Garriga and Hedlund (2020), Favilukis, Ludvigson and Van Nieuwerburgh (2017) and Greenwald and Guren (2024) each study the short-run impact of macroeconomic and financial shocks during the 2000s Global Financial Crisis. Kinnerud (2024) studies the effects of monetary policy shocks. Diamond, Landvoigt and Sánchez (2024), Gamber, Graham and Yadav (2023) study the impact of macroeconomic and policy shocks during the COVID-19 pandemic. Other papers study the long-run impact of changes in housing policies such as mortgage interest tax deductions (Karlman, Kinnerud and Kragh-Sørensen (2021a), Rotberg and Steinberg (2024)), stamp duty (Cho, Li and Uren (2024b)), and investor tax concessions (Cho, Li and Uren (2024a)).

Related to our own paper, Chodorow-Reich, Guren and McQuade (2024) study the impact of macroeconomic changes on the US housing market over the medium-term. They argue that the mid-2000s Financial Crisis followed a boom-bust-rebound pattern where house price increases tracked an increase in fundamentals over the medium-run. They model households as having diagnostic expectations, so that initial shocks generate short-run optimism about the future which generates a short-run boom and bust before returning to the medium-term growth path. We study the effect of longer-run changes in real interest rates, but also show that this leads to persistent increases in house prices. In Australia this has resulted in a long-term decline in the homeownership rate. Under the diagnostic expectations in Chodorow-Reich *et al* (2024), households extrapolate recent housing market growth and assume that growth will continue to be high in the future. In contrast, we assume that households are myopic and extrapolate the levels of current housing market equilibrium outcomes into the future.

Our paper also follows recent literature using heterogeneous agent life-cycle models to study various novel features of the Australian housing market. Cho *et al* (2024a) model the influence of landlord investment subsidies on rents, house prices, and homeownership. Cho *et al* (2024b) model the influence of home purchase taxes, known as stamp duty, on housing affordability and homeownership. Graham (2024) models the utilization and benefits of mortgage offset accounts. Graham and Sharma (2024) studies short-run fluctuations in homeownership due to transitory monetary policy shocks. ViforJ, Graham, Cigdem-Bayram, Phelps and Whelan (2023) is related to our paper as they consider the effect of long-run changes in interest rates on house prices and the homeownership rate. They suppose that the Australian housing market was in steady state in 1994, and consider the effect of moving to a new steady state equilibrium with interest rates as they were in 2017. In their model, house prices rise by 30 percent and homeownership falls by 15 percent. In comparison, our dynamic experiments predict a 40 percent rise in house price-to-income ratios, and a decline in homeownership for households under age 40 of 16 percent. Our work provides much more detail about what is driving these changes in homeownership, particularly the effect of changing downpayment requirements, stamp duty costs, and rent-to-price ratios.

Several papers have examined the long-run changes in the housing market, particularly in terms of homeownership and affordability trends. For example, Fisher and Gervais (2011) and Cobb-Clark and Gørgens (2014) look at demographic factors, including child-rearing preferences, delayed marriage, and longer educational periods, as non-economic contributors to declining homeownership. A report by the of Australia (2015) suggests that lower marriage rates and higher house prices are significant contributors to declining homeownership. Whelan, Atalay, Barrett, Cigdem-Bayram and Edwards (2023) shows that higher price-to-income ratios are associated with a lower likelihood of homeownership among young households. Relatedly, Ryan and Moore (2023) shows that in 1995 a 20 percent down payment on the median home was equivalent to about 7 months of gross income, but that this had increased to 12 months by 2019. Garvin, La Cava, Moore and Wong (2024a), Garvin, La Cava, Moore and Wong (2024b) document that rising stamp duty has resulted in a significant increase in transaction costs for home buyers. Garvin *et al* (2024a) shows that stamp duty payments increased from 1.5 months of take-home pay in 1995 to approximately 4.5 months by 2019. Our model is consistent with these empirical findings and provides a structural interpretation of how these factors contribute to observed homeownership patterns.

2. Model

We build a heterogeneous agent life-cycle model of housing decisions to study the declining trend in Australian homeownership rates in recent decades. Households in the model face idiosyncratic income risk, can save in a risk-free asset, may rent or own housing, and may finance home purchases with long-term mortgages originated subject to LTV and PTI constraints. We calibrate the model to an initial steady state and then study the effect of a long-run decline in real interest rates on equilibrium house prices and homeownership rates.

2.1. Household environment

Demographics. Time is discrete and indexed by t. Households live for J years with their age indexed by $j = 1, 2, ..., J$. Households work from age 1 to J^{ret} and are retired from age

$J^{ret}+1$ to J. They die with certainty at the end of age J.

Preferences. Households enjoy utility from non-durable consumption c and consumption of housing services s through the utility function:

$$u(c_{j,t}, s_{j,t}) = \frac{(c_{j,t}^{\alpha} s_{j,t}^{1-\alpha})^{1-1/\gamma}}{1-1/\gamma}.$$

α measures taste for non-durable consumption relative to housing services, and γ is the intertemporal elasticity of substitution. At the end of life, households enjoy warm-glow bequests over any remaining wealth $q'_{J,t}$ that is determined following decisions in the terminal period J. The bequest motive takes the form:

$$u^B(q'_{J,t}) = B\frac{(1+q'_{J,t})^{1-1/\gamma}}{1-1/\gamma}. \tag{1}$$

B controls the strength of the bequest motive and the bequest $q'_{J,t}$ is equal to the household's net wealth left behind when they die, as defined below.

In addition to the flow utility over consumption, households also receive taste shocks each period over the different housing options available to them. These taste shocks reflect idiosyncratic shifts in preferences that govern whether a household might prefer to rent or own on the margin. We describe these taste shocks in detail below.

Income. Household income is exogenous and follows a standard deterministic-stochastic process. Note that household income is not a function of time so we drop the subscripts t. During working life for household i, income comprises a deterministic age-specific component χ_j, an idiosyncratic random walk component w_{ij}, and an idiosyncratic transitory shock ϵ_{ij}:

$$\log y_j = \chi_j + w_{ij} + \epsilon_{ij}, \quad \epsilon_{ij} \sim \mathcal{N}(-0.5\sigma_\epsilon^2, \sigma_\epsilon^2)$$

where

$$w_{ij} = w_{ij-1} + \eta_{ij}, \quad \eta_{ij} \sim \mathcal{N}(-0.5\sigma_\eta^2, \sigma_\eta^2).$$

Denote $z_{ij} = \exp(\chi_j + w_{ij})$ as permanent income.

In reality, the Australian retirement system is a complex mix of private savings, a means-tested public pension, and a compulsory tax-preferred superannuation system. We abstract from these complications and assume that retirement income is simply proportional to end of working-life earnings. That is, during retirement households receive a constant pension equal to a fraction Γ^{ret} of their permanent income in the last year of their working life: $y_{ij} = \Gamma^{ret} z_{iJ^{ret}}$ for $j > J^{ret}$.

Liquid savings. Households can save in a risk-free liquid asset a with a one-period real interest rate r_t. Borrowing in the liquid account is not allowed.

Housing. Housing services s can be obtained by renting at a unit price p_t^r or owning a house, with a per-unit purchase price p_t^h. Rental house sizes are chosen from a grid $S = \{\underline{s}, s_1, s_2, ..., \bar{s}\}$. Similarly, owner-occupied house sizes are chosen from a grid $H = \{\underline{h}, h_1, h_2, ..., \bar{h}\}$, which is a proper subset of rental housing grid S.[2] A household who owns or buys a house of size h' receives a service flow equal to the size of their current house $s = h'$. We assume that households cannot be landlords. This contrasts with Cho *et al* (2024a), but significantly simplifies out analysis. We discuss the provision of rental units in housing market equilibrium in Section 2.4.

Transaction and maintenance costs. When a household buys a house they must pay stamp duty $SD_t(p_t^h h')$, which is a function of the value of the house being bought. We describe how we capture the progressivity of Australian stamp duty schedules in section 3.1. Homeowners pay a maintenance cost $\delta h'$ in each period of homeownership. Home sellers pay a transaction cost $\kappa^{sell} h'$. Note that both of these costs are proportional to house size, rather than house value as is typical in the literature. This is because the model is implicitly detrended relative to average income growth, and thus the house price p_t^h is a measure of the price-to-income ratio. Our assumption is that maintenance and sales costs growth in line with income, rather than house prices.

Mortgages. Households can finance property purchases using long-term non-defaultable mortgages. The interest rate paid on next-period mortgage balances r_t^m is a constant spread ζ^m above the risk-free rate: $r_t^m = r_t + \zeta^m$. We assume that mortgages fully amortise over the remaining lifetime of the mortgagor and that they must be repaid in full by the beginning of age J. An age-j mortgagor with beginning-of-period mortgage balance m faces a required repayment equal to

(2) $$\pi_j(m, r_{t-1}^m) = \frac{r_{t-1}^m (1 + r_{t-1}^m)^N}{(1 + r_{t-1}^m)^N - 1} m$$

[2]We assume that the smallest house size available for purchase is larger than the smallest rental property ($\underline{h} > \underline{s}$), which is standard in the literature.

where $N = J - j + 1$ and r^m_{t-1} is the relevant mortgage rate for payments made this period. New borrowers make their first mortgage repayment in the period following origination. A household's mortgage balance evolves according to:

$$m' = (1 + r^m_{t-1})m - \pi_j(m). \tag{3}$$

A household who takes out a new loan m' cannot borrow more than a fraction θ^{LTV} of the house value:

$$m' \leq \theta^{LTV} p^h_t h'. \tag{4}$$

Additionally, new borrowers face a payment-to-income limit.[3] Under the PTI limit, mortgage balances must be small enough that the first required repayment (assessed using the current period's mortgage rate) is less than or equal to a fraction θ^{PTI} of the borrower's permanent income in the period of origination. The PTI limit faced by an age-j household who takes out a loan m' is

$$\pi_{j+1}(m', r^m_{t-1}) \leq \theta^{PTI} z_{i,j}. \tag{5}$$

Mortgagors may refinance by paying a fixed cost κ^{refi}, and enter a new mortgage contract subject to the LTV and PTI constraints. If a mortgagor wants to make a repayment larger than $\pi_j(m)$ they have to refinance.

2.2. Household decision problems

The household state vector is $\mathrm{s} = (z, h, m, x)$, where z is permanent income, h is the owned housing stock, m is outstanding mortgage debt, and x is cash-on-hand. Cash on hand is given by current income and the return on liquid assets: $x = y + (1 + r_{t-1})a$. We also define a household's cash-on-hand after selling their beginning-of-period housing stock and repaying any outstanding debt $\tilde{x}$ as

$$\tilde{x} = x + (p^h_t - \kappa^{sell})h - (1 + r^m_{t-1})m.$$

Let $\mathbb{V}_j(\mathrm{s})$ be the value function of an age-j household. Each period, households make a

[3] Graham (2024) and Graham and Sharma (2024) model simple Net Income Surplus constraints, which are conceptually and similar to PTI constraints but closer to actual borrowing restrictions imposed by Australian banks and regulators. However, the implementation of these constraints is very similar to the PTI constraints adopted in this paper.

discrete choice over renting, buying a new house, staying in their current property and making a regular mortgage repayment, or staying in the current property but refinancing their mortgage. We now define each of the choice problems in turn.

The renter's problem is

$$
\begin{aligned}
V_j^{\text{rent}}(z,\tilde{x}) &= \max_{c,s}\ u(c,s)+\beta\mathbb{E}_t[\mathbb{V}_{j+1}(z',h',m',x')] \\
&\text{s.t.} \\
c+a'+p^r s &= \tilde{x} \\
s &\in S \\
h' &= 0, \quad m'=0, \quad x'=y'+(1+r_t)a'
\end{aligned}
\tag{6}
$$

The budget constraint says that expenditure on non-durable consumption and rent, plus liquid savings equals cash-on-hand, plus net proceeds from the sale of any housing owned at the beginning of the period. The choice of rental house size is restricted to the grid S. Finally, renters do not own housing and cannot take out or carry forward a mortgage.

The buyer's problem is:

$$
\begin{aligned}
V_j^{\text{buy}}(z,\tilde{x}) &= \max_{c,h',m'}\ u(c,h')+\beta\mathbb{E}_t[\mathbb{V}_{j+1}(z',h',m',x')] \\
&\text{s.t.} \\
c+a'+\delta h' &= \tilde{x}-p_t^h h'-SD_t(p_t^h h')+m' \\
m' &\leq \theta^{LTV} p_t^h h' \\
\pi_{j+1}(m',r_{t-1}) &\leq \theta^{PTI} z \\
h' &\in H \\
x' &= y'+(1+r_t)a'
\end{aligned}
\tag{7}
$$

Here, the 'expenditure' (left) side of the budget constraint now includes a maintenance cost on the new house. The 'available resources' (right) side reflects the purchase price of the property being bought, stamp duty, and the amount of new debt taken out. The newly originated mortgage is subject to the LTV and PTI limits. The choice of house size is restricted to be in H.

The stayer's problem is:

$$
\begin{aligned}
V_j^{\text{stay}}(z,h,m,x) &= \max_c u(c,h) + \beta \mathbb{E}_t[\mathbb{V}_{j+1}(z',h',m',x')] \\
&\text{s.t.} \\
c + a' + \delta h + \pi_j(m, r_{t-1}) &= x \\
h' &= h \\
m' &= (1 + r^m_{t-1})m - \pi_j(m) \\
x' &= y' + (1 + r_t)a'
\end{aligned} \tag{8}
$$

Here, beginning-of-period house size h and outstanding mortgage debt m enter as state variables in the decision problem. This is because h and m directly determine next period's house size h' and mortgage debt m', respectively.

Finally, the refinancer's problem is:

$$
\begin{aligned}
V_j^{\text{refi}}(z,h,\tilde{x}) &= \max_{c,m'} u(c,h) + \beta \mathbb{E}_t[\mathbb{V}_{j+1}(z',h',m',x')] \\
&\text{s.t.} \\
c + a' + \delta h &= \tilde{x} - (p^h_t - \kappa^{sell})h + m' - \kappa^{\text{refi}} \\
m' &\leq \theta^{LTV} p^h_t h \\
\pi_{j+1}(m', r_{t-1}) &\leq \theta^{PTI} z \\
h' &= h \\
x' &= y' + (1 + r_t)a'
\end{aligned} \tag{9}
$$

This looks very similar to the buyer's problem, except that there is no choice over house size. Accordingly, current house size h enters directly as a state variable, and we subtract proceeds from selling $(p^h_t - \kappa^{sell})h$ from the household's available resources on the right-hand-side of the budget constraint.

In the the last period of life households cannot originate a new mortgage, so refinancing is not an option. The discounted continuation value function on the right-hand-side of the Bellman equations are replaced by the bequest motive function (1). The bequest motive function takes takes residual wealth at the time of death as its argument: $q' = a' + p^h_t h'$ since mortgages are fully paid off at the beginning of age J. We write down the age-J decision problems in Appendix A.1

2.3. Taste shocks

We assume that households face discrete choice-specific taste shocks as in Iskhakov, Jørgensen, Rust and Schjerning (2017) and others. Taste shocks are commonly used across many applications in economics[4], but they are less common in quantitative housing models like ours. We use taste shocks because, by injecting noise into households' discrete choices, they dampen the otherwise very strong link between a household's financial position and their homeownership status in the model. This helps the model match the data because there are many factors that might influence a household's decision to rent, buy, stay-put, or refinance in reality that the model does not see. [5]

Let a household's discrete choice over whether to rent, buy, stay, or refinance be captured by the variable $k \in \{\text{rent, buy, stay, refi}\}$. The taste shocks $\xi(k)$ are additively separable, independent and identically distributed, and have a type 1 extreme value distribution with scale parameter σ_ξ. The inclusion of tastes shocks means that we can write the household's value function $\mathbb{V}_j(\mathbf{s})$ as

$$\mathbb{V}_j(\mathbf{s}) = \max_k \left\{ V_j^k(\mathbf{s}) + \sigma_\xi \xi(k) \right\}. \tag{10}$$

for $k \in \{\text{rent, buy, stay, refi}\}$ and where $V_j^k(\mathbf{s})$ are the discrete-choice specific value functions defined above. The iid EV-1 distributional assumption leads to well-known analytical formulas for the household's value function $\mathbb{V}_j(\mathbf{s})$ and choice probabilities, which we describe in Appendix A.2.

2.4. Supply side

The supply side of the model is very simple, and closely resembles the supply side in Kaplan *et al* (2020) and Karlman, Kinnerud and Kragh-Sørensen (2021b). There is supply curve for the aggregate quantity of housing services (which we allow to be upward sloping or vertical in the quantitative analysis). You can think of this aggregate supply (or stock) of housing as the total 'square feet' of housing in the economy. In equilibrium the house price adjusts each period so that aggregate demand for housing services equals supply; there is no vacant housing. The rental rate is pinned down by an equation which links it to the user-cost of owning housing; the rental sector is willing to provide any quantity of rental housing

[4]Mongey and Waugh (2024) list several examples.

[5]For example, a large draw of the taste shock associated with buying a new house might stand in for the impending arrival of a child, which might give a household a stronger-than-usual urge to buy a house today; a low draw for the refinancing taste shock might stand in for a busy period where a household cannot find the time to refinance their mortgage, even though it might otherwise be optimal for them to do so.

at this equilibrium rental rate. The implicit assumption here is that the aggregate stock of housing services in the economy (or aggregate square footage) is flexibly composed of rental and owner-occupied housing. In other words, a square foot of rental housing in one period can be costlessly converted into a square foot of owner-occupied housing in the next. Given that we are interested in longer-run dynamics, and it is common for dwellings in Australia to transact between investors and owner-occupiers, we think that this implicit convertibility assumption is appropriate. We formalise this supply side below.

Rental market. We assume that the rental rate p_t^r is set according to a user-cost equation, which relates rents to house prices, maintenance costs, and interest rates:

$$p_t^r = (1+\phi)p_t^h + \delta - \frac{1}{1+r_t}\mathbb{E}[p_{t+1}^h] \tag{11}$$

$\phi > 0$ is a parameter, which creates a wedge between the (unlevered) user-cost of owning housing and the rental rate, in-turn giving households an incentive to own housing. Fox and Tulip (2014) find, using aggregate time series, that the user-cost of owning has roughly tracked the cost of renting in Australia over long horizons. Equation (11) forces the model to be consistent with that evidence. Modelling rents in this way is also convenient because it means we only need to solve for one equilibrium price (the house price) when computing transition dynamics.

Housing supply. We assume an isoelastic supply curve for the aggregate stock of housing services:

$$p_t^h = \left(\frac{H_t^S}{\bar{H}}\right)^{1/\vartheta} \tag{12}$$

Here H_t^S is the supply of housing services, ϑ is the elasticity of housing supply, and $\bar{H}$ is aggregate housing services in the initial steady state.

2.5. Bequests

We follow Karlman *et al* (2021b) in the treatment of bequests. The government collects bequests from households who die. After collection, the government earns interest on liquid asset balances, sells bequeathed houses and incurs selling costs. The net amount of bequests collected is:

$$BQ_{t+1} = \int \left((1+r_t)a'_{Jt}(\mathbf{s}) + (p_{t+1}^h - \kappa^{sell})h'_{Jt}(\mathbf{s})\right) d\mu_{Jt}(\mathbf{s}) \tag{13}$$

where we are integrating over the period-t distribution of age-J households $\mu_{Jt}(\mathbf{s})$ over idiosyncratic states. In the initial steady state we assume that the government distributes a portion of total bequests to newborn ($j = 1$) households to fund their initial liquid asset holdings. The remainder leaves the model. In our transition experiments we distribute any increase in bequests relative to the the initial steady state to newborn households according to their share of what total newborn asset holdings would have been if the extra bequests were not distributed.

2.6. Steady state equilibrium

Given interest rates (r, r^m) and an initial housing stock $\bar{H}$, a steady state equilibrium of this economy is characterised by a house price p^h such that:

- the rental rate is given by (11) evaluated at the time-invariant house price:

$$p^r = (r/(1+r) + \phi)p^h + \delta$$

- given (r, r^m, p^h, p^r), households solve the stationary version of their decision problem, giving rise to an invariant distribution $\mu_j(z, h, m, x)$ for each j;
- the housing market clears:

$$\sum_j \int s_j d\mu_j(z, h, m, x) = (p^h)^{\vartheta} \bar{H}. \tag{14}$$

In the initial steady state we exogenously fix the house price to be one; $p_0^h = 1$. The rental rate is then given by (11) $p_0^r = r_0/(1 + r_0) + \phi + \delta$. Given initial interest rates and prices we solve the household's problem, and simulate a large number of households who behave according to these decision rules. We assume that housing supply is perfectly elastic in this initial steady state so that the housing market clears by assumption. This gives us our initial housing stock $\bar{H}$, which is simply equal to aggregate housing demand in the initial steady state.

3. Calibration

Our goal is to parameterise the model's initial steady state so that it resembles the Australian economy in 1995. To do this, we first take most parameters directly from the literature or data; these parameters are listed in Table 1. We then jointly calibrate the remaining few parameters to minimise the distance between chosen model moments and

Table 1: Externally Calibrated Parameters

Parameter	Description	Value
γ	Intertemporal elasticity of substitution	0.5
$\{\chi_j\}$	Age-profile for income	See text
Γ^{ret}	Retirement replacement rate	0.6
σ_ϵ	Standard deviation of transitory income shock	0.1
σ_η	Standard deviation of permanent income shock	0.1
σ_{w_0}	Standard deviation of initial permanent income	0.2
δ	Depreciation rate	0.02
θ^{LTV}	Maximum LTV at origination	0.85
θ^{PTI}	Maximum PTI at origination	0.4
κ^{sell}	Proportional selling cost	0.025
κ^{refi}	Fixed refinancing/prepayment cost	$2,500
λ_0	Stamp duty function level in 1995	0.02
τ	Stamp duty function progressivity	0.25
$\{a_0\}$	Newborn liquid wealth	See text
r_0	Risk-free rate in 1995	0.04
ζ^m	Mortgage rate spread	0.02
ϑ	Housing supply elasticity	$\{0.07, 0.4\}$

their empirical values, most of which come from the 1994-5 wave of the Survey of Income and Housing (SIH). The fitted parameters and moments are listed in Table 2. Below we describe these parameter choices and our internal calibration procedure in more detail. Then in section 3.4 we describe how we choose the magnitude of the interest rate decline to feed into the model, and our choice of the aggregate housing supply elasticity, both of which are crucial to the quantitative results.

3.1. Externally calibrated parameters

Demographics and IES. The model period is one year. Households enter the model at age 25, which corresponds to $j = 1$. They work until the end of age 64. They are retired from 65 ($J^{ret} = 41$) and die at the end of age 74 $(J = 50)$. The intertemporal elasticity of substitution γ is 0.5.

Income process. We use a simple 'tent-shaped' deterministic age profile for income following Ma and Zubairy (2021):

$$\chi_j = 1 + 0.5 \times \left(1 - \frac{|j - J^{peak}|}{J^{peak} - 1}\right) \text{ for } j < J^{ret} \tag{15}$$

This profile implies that average earnings grows linearly, peaking at age J^{peak}, and then declines linearly at the same rate until the year before reitrement. Average earnings at age J^{peak} is 50 per cent higher than at $j = 1$. We choose J^{peak} to be 26, which corresponds to a peak earnings age of 50. We set the standard deviations of the transitory and permanent shocks (σ_ϵ, σ_η) to both be 0.1, which is fairly representative of values used in the literature (Druedahl and Jøregenson (2017)). Newborns entering the model draw an initial value for the random walk component of income w_0 from a normal distribution: $w_0 \sim \mathcal{N}(0, 0.2^2)$. We set the retirement replacement rate Γ^{ret} to be 0.6.

Housing and mortgages. We set the depreciation rate δ to be 0.02; the maximum LTV at mortgage origination θ^{LTV} to be 0.85; and the maximum PTI at origination θ^{PTI} to be 0.4. We set the fixed refinancing cost κ^{refi} to be $2,500 in 2019 dollars. These are all standard values from the literature.

Stamp duty function. Effective stamp duty rates are generally higher for more expensive properties in Australia. To capture this progressivity we follow Heathcote, Storesletten and Violante (2017) and Cho *et al* (2024b) by modelling the stamp duty function as:

(16) $$SD_t(p_t^h h') = \lambda_t (p_t^h h')^{1+\tau}$$

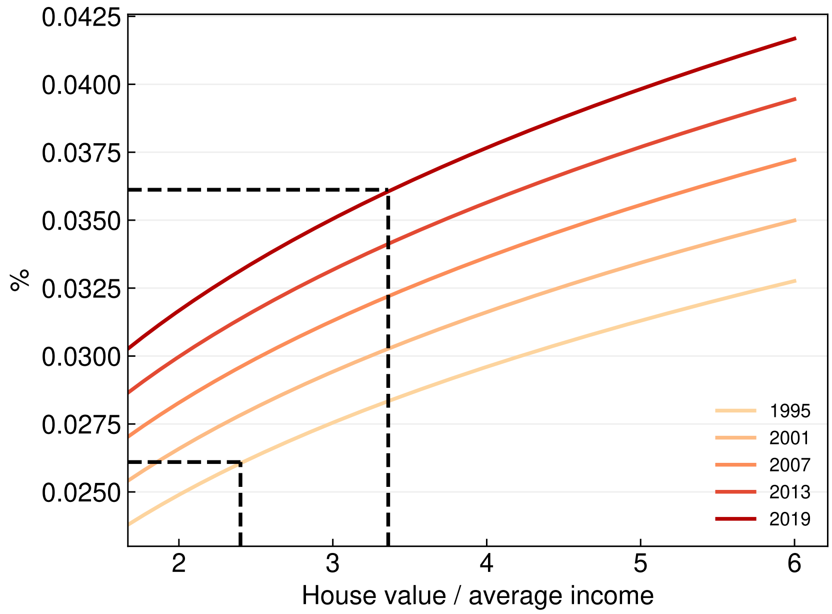
τ is the elasticity of effective stamp duty rates $SD_t(p_t^h h')/p_t^h h'$ to house values, so it can be thought of as a measure of progressivity. λ_t controls the average level of stamp duty across house values. We use a similar procedure to Cho *et al* (2024b) to calibrate the stamp duty function parameters λ_t and τ. We obtain stamp duty schedules from state government websites. We compute effective stamp duty rates for each state over a vector of house values. We then aggregate these state-level empirical stamp duty rate functions using dwelling stock shares from Census data. Our functional form for the stamp duty function in (16) implies a log-linear relationship between effective stamp duty rates and house value. Dropping the time subscripts in (16) and taking logs implies

$$\log(SD(p^h h')) = \log(\lambda) + (1+\tau)\log(p^h h')$$

We estimate λ and τ using OLS, which yields $\hat{\lambda} = 0.0013$ and $\hat{\tau} = 0.25$. To convert into model units, we scale the argument of the stamp duty function by the ratio of the median house price in 1995 from CoreLogic data ($125,000) to the median house price in the model's initial steady state (around 2.9), which we implicitly target in our internal calibration (see below). Plugging $\hat{\lambda}$ and this scaling factor into (16) implies $\lambda_0 = 0.02$.

Stamp duty schedules have not changed much over time despite very large increases in nominal house prices. And because rates are generally higher for more expensive properties, this means there has been significant bracket creep over time (Garvin *et al* (2024a)).

Figure 3: Stamp Duty Rates in the Model For Selected Years



Sources: Authors' computations.

Some of this bracket creep comes from higher house price-income ratios, and some comes from nominal income growth. Our model is designed to capture the former, but does not feature the latter. To capture the additional bracket creep due to rising nominal incomes we allow λ_t to increase over time. Average nominal household disposable income grew by a factor of 2.62 between 1995–2019. During our transition experiments we let λ_t grow linearly by a factor of $2.62^{\tau} = 1.27$ from its initial value of 0.02 to 0.025 in 2019. Figure 3 illustrates how this works. The model economy starts in an initial steady state, representing 1995, with a median house value to average income ratio of around 2.4 (we target this moment in our calibration; see below). The stamp duty rate on this median-valued house is around 2.6 per cent in 1995. As the transition experiment proceeds, the stamp duty function shifts up. Suppose the house price to income ratio increases by a factor of around 1.4 over 1995–2019, which is in line with the observed increase when using constant-quality house prices. The stamp duty rate on this median-valued house would be around 3.6 per cent in 2019.

Newborn liquid wealth. Newborn households enter the model with initial liquid wealth a_0 drawn from a distribution. We calibrate this distribution to resemble the empirical distribution of wealth of young households, and its correlation with earnings, following Kaplan *et al* (2020), and Karlman *et al* (2021b). We pool all households with heads aged 25–29 who appear in any of the wealth module waves of the Household, Income and Labour Dynamics in Australia (HILDA) Survey during 2002–2018. We divide these households into 21 groups based on their real earnings in 2019 dollars. For each group, we calculate the share with net wealth above $1,000 in 2019 dollars and median wealth conditional on having wealth above $1,000. We scale median wealth for each group by median real earnings of working-age households (25-64) in the pooled HILDA data. In the model, we divide newborns into 21 groups based on their initial earnings. For each group we assign a share of households zero initial wealth, based on the share with low wealth in HILDA. The remaining households in each group are given initial wealth equal to the median wealth-to-earnings ratio for that group in the HILDA data scaled up by median earnings of working-age households in the model.

3.2. Fitted parameters

We jointly calibrate the remaining parameters $\{\beta, \alpha, B, \underline{h}, \phi, \sigma_\xi\}$ to minimise the distance between chosen model moments and their empirical values. Table 2 shows the fitted parameter values, the model moments and their empirical values. The data moments are from the 1994-5 Survey of Income and Housing (SIH) unless otherwise stated. Although the parameters are jointly identified, some moments are particularly informative about some parameters. We briefly describe our logic next. The discount factor β is informed by how much debt homeowners take on, which we measure using the mean LTV of homeowners. A higher β implies more savings and lower leverage. The utility function parameter α is informed by the median house price to average income ratio. If α is higher households want to spend less on housing, which lowers its value. We compute the empirical moment using the Australia-wide median sales price in 1995 from CoreLogic and divide this by average household disposable income from National Accounts data in 1995. The bequest motive parameter B is informed by the ratio of median net-worth of 65-74 year olds to the median net-worth of households aged 75+. A stronger bequest motive (higher B) means households dissave less during retirement, which lowers this ratio. We get the empirical moment from HILDA 2002. The three remaining parameters $\{\underline{h}, \phi, \sigma_\xi\}$ all affect homeownership in the model. A larger minimum house size $\underline{h}$ lowers homeownership. The rent wedge ϕ controls the price-rent ratio in the initial steady state, which younger agents are particularly sensitive to when deciding whether to rent or own. Finally, a larger taste shock scale σ_ξ loosens the otherwise strong link between a household's financial position and their homeownership status. We use the aggregate homeownership rate, the homeownership rate of under-40s, and the homeownership rate in the lowest income quintile to inform these parameters.

Table 2: Fitted Parameters and Moments

Parameter	Description	Value	Target moment	Model	Data
β	Discount factor	0.94	Mean LTV of homeowners	0.18	0.17
α	Non-durable share in utility	0.73	Median house value/mean income	2.37	2.38
B	Bequest motive	20.15	Median NW 65-74/median NW 75+	1.30	1.28
$\underline{h}$	Smallest ownable house size	2.8	Homeownership rate	0.74	0.71
ϕ	Rent wedge	0.02	Homeownership rate < 40	0.59	0.60
σ_ξ	Taste shock scale	0.13	Homeownership rate 1st inc. quint.	0.51	0.51

3.3. Steady state profiles vs. data

Figure 4 shows that the model reproduces the age-profiles of homeownership, house value relative to income, and leverage. In the model and in the 1994-5 SIH data around 55 per cent of 25-34 year olds own, compared to around 85 per cent of 55-64 year olds. The model produces slightly too little homeownership at very old ages (panel (a)). House value to income tends to rise over the life-cycle (panel (b)), while leverage of home owners declines (panels (c)-(d)).

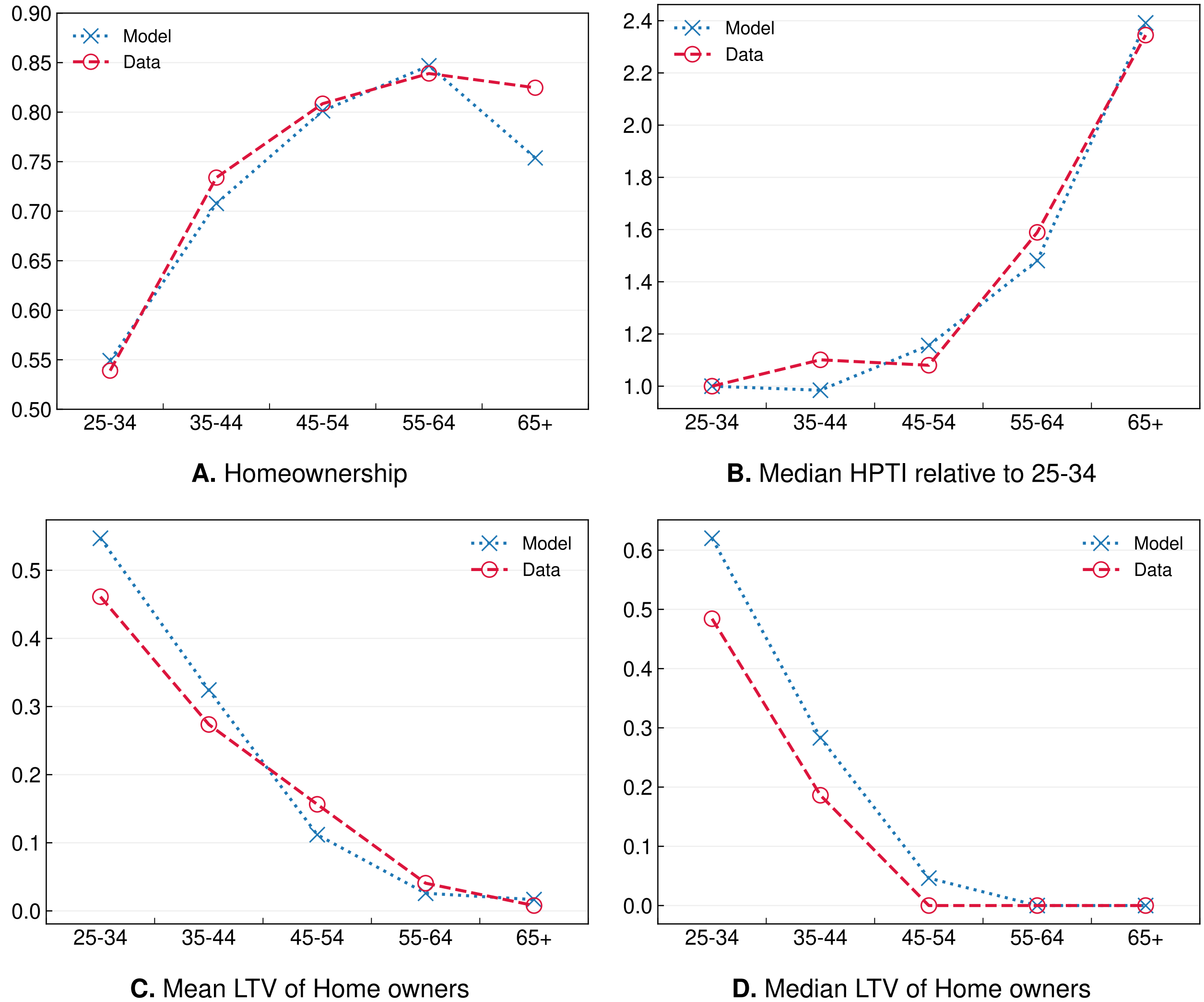
3.4. Interest rate decline and supply elasticity

Together, the magnitude of the fall in interest rates that we feed into the model, and the housing supply elasticity are crucial for determining how much house prices increase in our model simulations. A larger fall in rates for a given supply elasticity, or a smaller supply elasticity for a given decline in rates, results in a larger increase in the model house price and a larger fall in homeownership.

What is the appropriate real interest rate decline to feed into the model? There are two broad approaches one could take to calibrate this decline. The first is to rely on estimates of real yields on government bonds. Since we are mainly interested in the price of housing, which is a long-lived asset, it makes more sense to look at longer-term real yields than shorter-term yields. Updated estimates of the term structure model in Hambur and Finlay (2018) suggest that the 10-year real yield on Australian government bonds fell by about $4\frac{1}{2}$ percentage points over 1995–2019 (Figure 2(a)). Updated estimates from D'Amico *et al* (2018) term structure model suggest that 10-year real yields on US government bonds fell by around 3 percentage points over the same period.[6] The second

[6]Note that both of the numbers cited here include declines in government bond risk premia. Though the housing risk premium is distinct from the risk premium on government bonds, we think it is better to include the government bond risk premium when thinking about what interest rate decline to feed into the model rather than stripping it out completely. The updated estimates from DKW are available here: https://www.federalreserve.gov/econres/notes/feds-notes/DKW_updates.csv

Figure 4: Lifecycle Profiles in the Model's Initial Steady State



Sources: ABS; Authors' computations.

approach is to rely on estimates of long-run housing-specific discount rates. The best evidence on housing discount rates comes from the UK, where researchers have exploited variation in the duration of apartment leaseholds. Bäcker-Peral *et al* (2023) estimate that the long-run housing discount rate in the UK fell by around 2 percentage points between the early 2000s and 2020. In the same setting, but with different methodology, Bracke, Pinchbeck and Wyatt (2018), estimate that the housing discount rate fell by around 1.6 percentage points between 1987–1992 and 2004–2013. Given the variation in these sets of estimates, it makes sense to show results for a range of interest rate declines. We settle on three values: -2, -3, and -4 percentage points over 1995–2019.

Supply elasticity estimates for Australia also differ widely in the literature. Moreover, identification issues and uncertainty around the empirical estimates means looking at a range of estimates is probably more useful than picking a particular number for ϑ. We test an elasticity of 0.07 from Saunders and Tulip (2019) and 0.4 from Gitelman and Otto (2012). The Saunders and Tulip (2019) estimate is for the aggregate dwelling stock, so is arguably more suitable for our model than the Gitelman and Otto (2012) estimate which also includes spatial substitution.

To summarise, let $\Delta r_{1995\to2019}$ denote the fall in real interest rates between 1995 and 2019 that we feed into the model. We show simulation results for $\Delta r_{1995\to2019} \in \{-0.02, -0.03, -0.04\}$ and $\vartheta \in \{0.07, 0.4\}$. We treat the pair $\{\Delta r_{1995\to2019} = -0.03, \vartheta = 0.07\}$ as our benchmark parameterisation.

4. Quantitative Effects of Declining Real Interest Rates

In this section we apply a sequence of unanticipated and permanent interest rate shocks to our model economy and study the quantitative effect on homeownership rates. The model economy starts in an initial steady state in year $t = 0$ taken to represent the Australian economy in 1995. From this starting point, we hit the economy with a sequence of equally-sized annual negative interest rate shocks that lower the risk free-rate r_t and the mortgage rate r_t^m by the same amount.[7] For our main analysis we assume that each of these annual shocks is permanent and unanticipated. We also assume that households and the rental sector expect future house prices and rents to remain at their period-t levels forever. This means that households and the rental sector are surprised by the new (lower) interest rates and equilibrium prices every period.[8] Importantly, the economy does not jump to the new steady state following each interest rate shock. Instead, following each year's change in rates, the house price and rental rate adjust, households update their optimal decisions, and the economy begins a long transition to the new steady state. However, the following year this transition is interrupted by a new unexpected interest rate shock, and the process repeats, until $t = 24$, which represents calendar year 2019. After that, rates do not change, and the economy eventually reaches a new low-rate state state.

In Figure 11 we compare the transitions paths of house prices and rents under constant-price expectations to a perfect-foresight experiment in which households are fully surprised

[7]This implies that the mortgage spread is kept constant in our transition experiments. In reality, the mortgage spread has moved around but the decline in risk-free rates is larger and the focus of our paper.

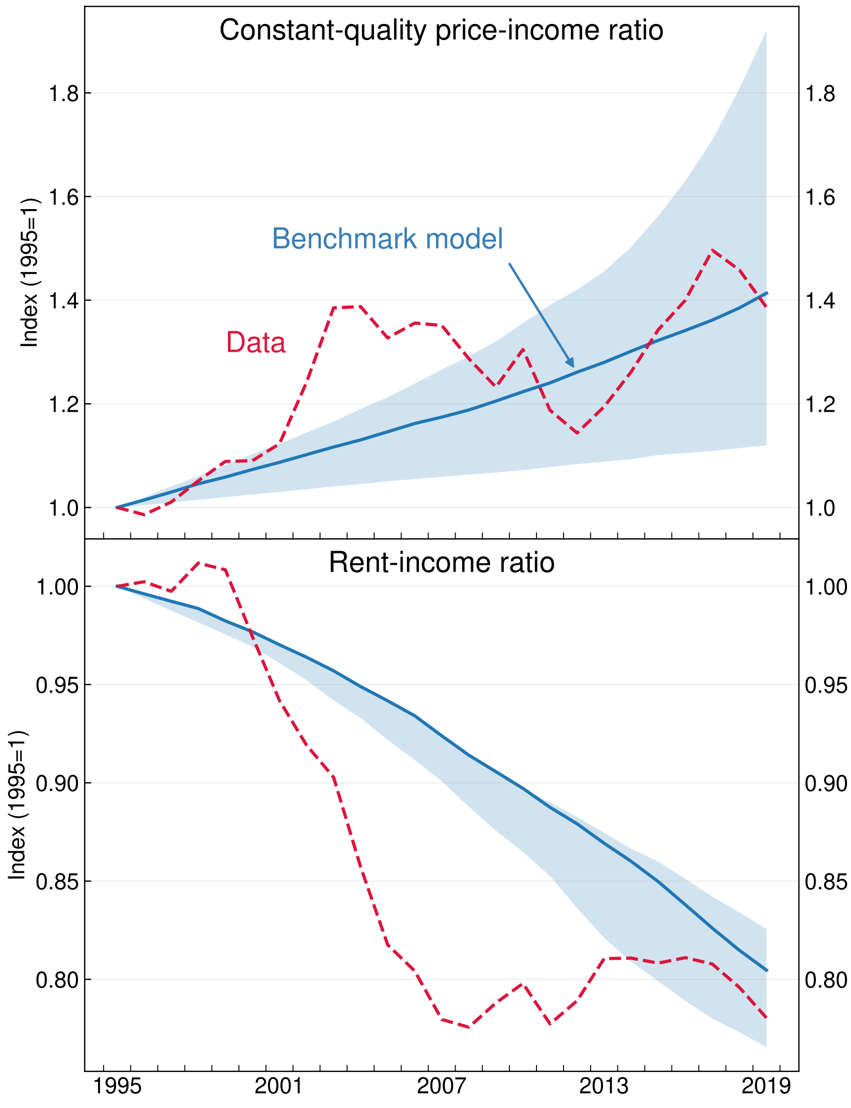
[8]That is, in period $t = 1, ..., T$, given a distribution $\mu_{jt}(z, h, m, x)$ for each j, households solve their decision problem assuming that current-period interest rates and prices $(r_t, r_t^m, p_t^h, p_t^r)$ will prevail forever. In period $t + 1$ households are again surprised that interest rates have changed, and that the equilibrium house price and rent result from housing market clearing in period $t + 1$.

in period $t = 1$ to learn about the new exogenous path for interest rates $\{r_t, r_t^m\}_{t=1}^{\infty}$ that will prevail into the future. In a perfect-foresight equilibrium, households and the rental sector are fully informed about future equilibrium prices $\{p_t^h, p_t^r\}_{t=1}^{\infty}$ and optimize accordingly. As one might expect, the perfect-foresight experiment produces a front-loaded increase in the house price, which is inconsistent with the data. Similarly, bond market pricing (and survey data) indicate that the secular declines in interest rates over this period continually took market participants by surprise. For this reason, we opt for constant-price expectations in our main analysis.

4.1. House prices and rents

The top panel of Figure 5 compares the constant-quality house price-income ratios from our model simulations to the actual price-income ratio for 1995–2019. In the model, the constant-quality price-income ratio is measured simply by p_t^h because there is no aggregate income growth. The constant-quality house price data are from CoreLogic's Home Value Index, which we divide by average household income, before interest payments, from the National Accounts. The headline result here is that our benchmark model simulation, which applies a 3 percentage point interest rate decline and uses a housing supply elasticity $\vartheta = 0.07$, produces a reasonably accurate increase in house prices. In the benchmark simulation and in the data, the house price-income ratio increased by around 40 per cent, when prices are measured on a constant-quality basis. Around the benchmark, we show the range of model results using $\Delta r_{1995 \to 2019} \in \{-0.02, -0.04\}$ and $\vartheta \in \{0.07, 0.4\}$. All else equal, a smaller decline in rates, or more elastic supply, produces a smaller increase in the model house price. The bottom panel of Figure 5 shows that the model simulations also broadly match the decline in the rent-income ratio observed over 1995–2019.

Figure 5: Constant-Quality House Price-Income and Rent-Income Ratios in the Model and Data



Notes: The constant-quality house price in the model is p_t^h, and rent is p_t^r. For the benchmark model we apply a 3 percentage point interest rate decline, and use a housing supply elasticity $\vartheta = 0.07$. The blue shaded regions show the range of model outcomes using $\Delta r \in \{-0.02, -0.04\}$ and $\vartheta \in \{0.07, 0.4\}$.

Sources: ABS; CoreLogic; Authors' computations.

4.2. Homeownership rates by age and income

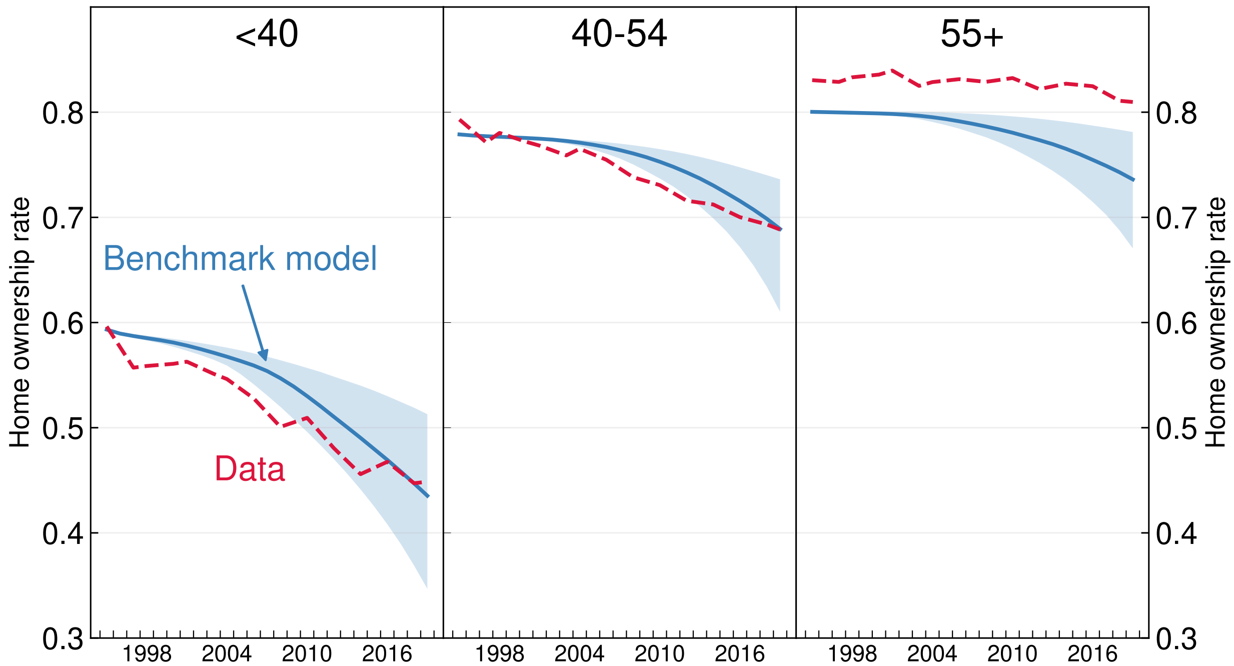
Figure 6 compares the time series of homeownership rates by age group from our model simulations to actual homeownership rates from the SIH. The benchmark model simulation generates falls in homeownership rates that closely match the data for the under-40 and 40-54 age groups; the model over-predicts the decline in homeownership in the 55+ age group. In the benchmark model simulation the homeownership rate of under-40s falls by around 16 percentage points, compared to a 15 percentage point fall in the data. Given the model is calibrated using mostly 1994/1995 data and cannot see the path of homeownership rates over this time, it does a remarkably good job of tracking the actual data over a 25 year period. As with house prices, it is possible for the model to over- or under-predict declines in homeownership rates depending on the magnitude of the interest rate decline run through the model, and the choice of supply elasticity. However, the benchmark simulation, which applies a 3 percentage point decline in rates and uses $\vartheta = 0.07$ produces time series for house prices, rents, and homeownership rates, which are all consistent with the data.

It is worth noting that Census data show a smaller decline in the under-40 homeownership rate than the SIH does (Figure 1). Accordingly, the benchmark model simulation over-predicts the decline in homeownership among under-40s when comparing to Census data rather than SIH. However, it is also worth noting that declining homeownership rates have been a target of substantial policy efforts not captured in the model, such as grants and concessionary stamp duty rates for first-home buyers. These policies might explain some of the over-sensitivity of homeownership rates to interest rates compared to the Census data.

Next, we compare homeownership by income in the benchmark model simulation and SIH data. Figure 7 plots homeownership rates by income quintile for under-65s in the model's initial steady state and the 1994/5 SIH data (left panel), and the benchmark simulation's prediction for 2019 and the 2019-20 SIH data (right panel). The main message is that the model does a reasonable job of matching the pattern of homeownership across income groups in both years. In the model and data, between 1995 and 2019 homeownership falls proportionally more for the lowest income quintile compared to the top two income quintiles.

Figure 8 probes the sensitivity of the path of under-40 homeownership to our assumptions about bequests and taste shocks. Panel (a) shows that when excess bequests (relative to the 1995 steady state) are distributed to newborn households, the under-40 homeownership rate is around 2 percentage points higher in 2019, compared to when these

Figure 6: Homeownership Rates by Age Group in the Model and Data



Notes: Homeownership data are from the 1994/5–2019/20 waves of the SIH. For the benchmark model results we apply a 3 percentage point interest rate decline over 1995–2019, and use a housing supply elasticity $\vartheta = 0.07$. The blue shaded regions show the range of model outcomes using $\Delta r \in \{-0.02, -0.04\}$ and $\vartheta \in \{0.07, 0.4\}$.

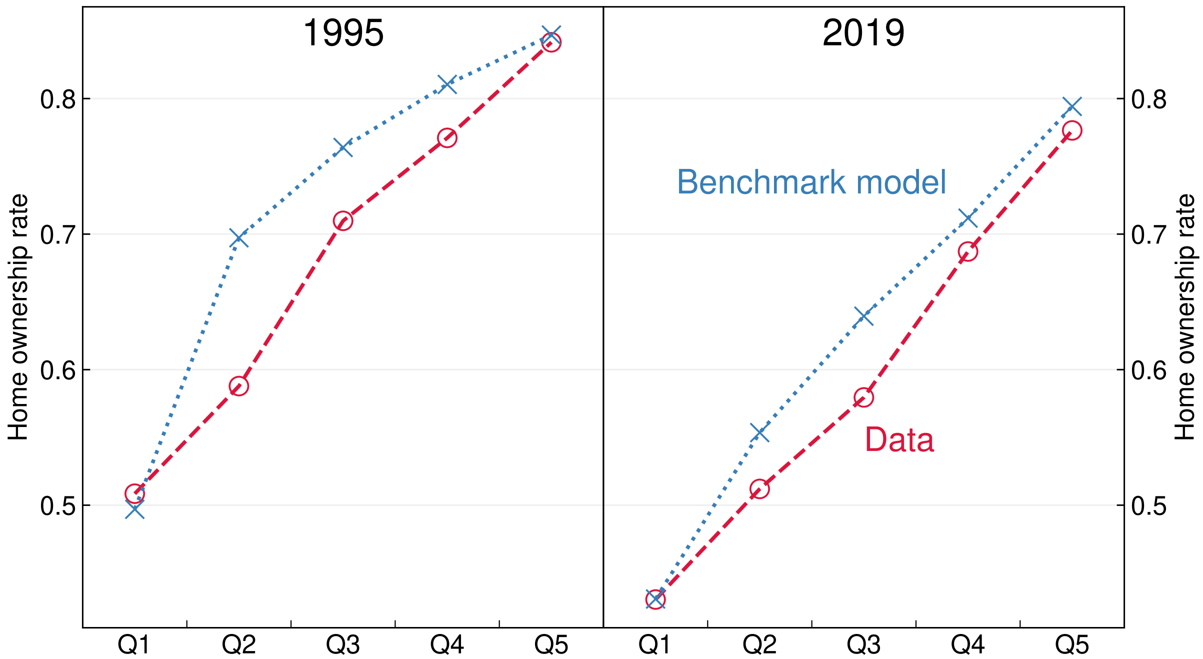
Sources: ABS; Authors' computations.

excess bequests leave the model. One could interpret this 2 percentage point boost as quantifying the impact of inheritance, and/or cash transfers from parents in supporting the homeownership rate of younger households over this period. However, for a few reasons, we think this is probably a lower bound estimate. First, while bequeathed housing wealth rises over time, bequeathed liquid wealth actually declines in our model simulations due to the lower risk-free return. This is inconsistent with evidence in La Cava and Wang (2021), who find that older households' liquid asset holdings have risen over time (relative to incomes). Second, to the extent that parents receive some warm-glow utility from helping their children buy a home, this suggests that parental transfers would be larger than the excess bequests captured in our simulations.

Figure 8(b) shows that the decline in under-40 homeownership is far more pronounced in the version of the model without taste shocks over the discrete housing choices.[9] This is unsurprising because without taste shocks, there is a much stronger correlation

[9] The no taste shock calibration sets $\sigma_\xi = 0.00001$. $\{\beta, \alpha, B, \underline{h}, \phi\}$ are calibrated to match the same empirical targets as in the benchmark model, except for the homeownership rate of households in the lowest income quintile. See Appendix B for details.

Figure 7: Homeownership Rates by Income Quintile in the Model and Data (Under-65s)



Notes: Homeownership data are from the 1994/5 and 2019/20 waves of the SIH. For the benchmark model results we apply a 3 percentage point interest rate decline over 1995–2019, and use a housing supply elasticity $\vartheta = 0.07$.

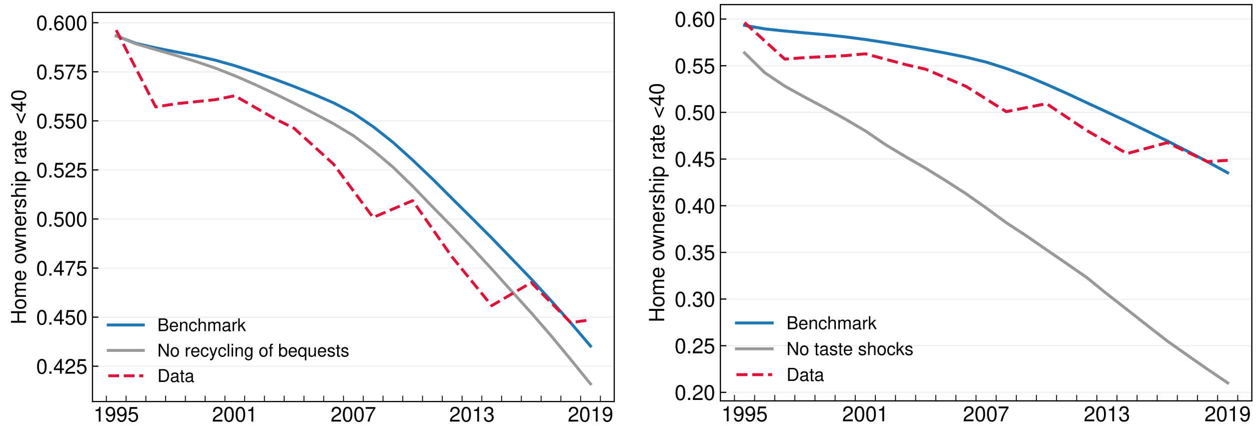
Sources: ABS; Authors' computations.

between a household's financial position and their homeownership status compared to the benchmark model. So the higher house price weighs more heavily on homeownership among under-40s in the model version without taste shocks.

4.3. The role of down-payment constraints and stamp duty

Now we explore the extent to which the increasing size of minimum down-payments, and rising stamp duty contribute to the decline in homeownership in the model. The minimum down-payment is fixed at 15 per cent of the value of the house being purchased, but because the price of housing increases over time (relative to income), a higher ratio of net wealth to income is required to purchase a given home. In the benchmark model simulation the 15 per cent down-payment on the median-valued house rises from around 35 per cent of average annual household income in 1995 to 50 per cent of average annual income in 2019 for the same house. This is a 40 per cent increase, which is equivalent to the rise in the model's house price. Stamp duty on the median-valued house doubles from around 6 per cent of average annual income in 1995 to 12 per cent of average annual income in 2019. Stamp duty rises by proportionally more than the house price because stamp duty

Figure 8: Sensitivity of the Under-40 Homeownership Rate



A. No recycling of bequests

B. No taste shocks

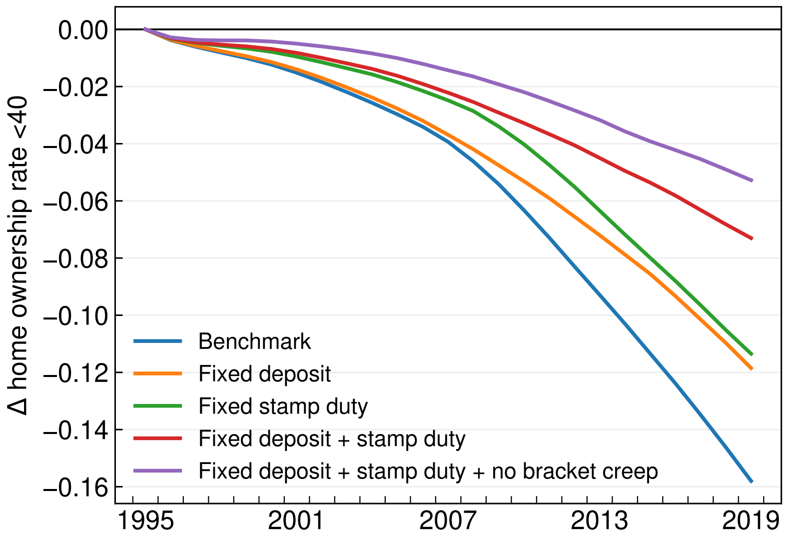
Notes: For the benchmark model results we apply a 3 percentage point interest rate decline over 1995–2019, and use a housing supply elasticity $\vartheta = 0.07$. 'No recycling of bequests' does not distribute any increase in bequests relative to the 1995 steady state to newborn households. 'No taste shocks' uses the calibration without taste shocks.

Sources: ABS; Authors' computations.

rates are progressive and affected by the bracket creep that occurred over 1995–2019, as illustrated in Figure 3.

To quantify the effects of these two forces in the model we re-do the benchmark simulation while individually switching off the tightening effect of the interaction of higher house prices and each of the down-payment requirement and stamp duty. To switch-off the tightening of the mortgage down-payment we hold the minimum down-payment fixed at 15 per cent of what the value of a house would have been in 1995 for the duration of the simulation. The idea is to make the down-payment constraint no more binding over time. Formally, we replace the LTV constraint in equation (4) with the condition: $m' \leq \theta^{LTV} p_0^h h'$. For example, this keeps the 15 per cent down-payment on the median-valued house in 1995 constant at around 35 per cent of average annual income for the duration of the simulation. We refer to this as the '1995 down' simulation in the upcoming figures. To switch off rising stamp duty, we calculate stamp duty based on the 1995 price regardless of the period-t price in the model. Formally, we use $p_0^h h'$ as the argument of the stamp duty function in equation (16) rather than $p_t^h h'$. Note that in this version of the simulation the stamp duty schedule still shifts up over time as in Figure 3 (that is λ_t is still increasing over time). We think it is important to consider this counterfactual because even if the house price-income ratio had remained flat over 1995–2019, rising nominal house prices would have resulted in higher effective stamp duty rates if the stamp duty schedules were left unchanged over time. Accordingly, we label this simulation as '1995 stamp with b(racket) c(reep)'. We can

Figure 9: Decomposition of the Decline in Homeownership Among Under-40s



Notes: 'Deposit' switches-off the tightening effect of rising minimum down-payments; 'Trans. costs' switches-off the tightening effect of rising buying and selling costs; and 'Depost + Trans. costs' switches both off. See text for details.
Sources: Authors' computations.

additionally keep $\lambda_t = \lambda_0 \forall t$, which implies that the stamp duty function in the model does not shift up over time.[10] We refer to the simulation which combines this constant λ condition with the other two conditions as '1995 down + stamp'.

Figure 9 shows the results of this model decomposition for the under-40 homeownership rate. In the benchmark simulation the under-40 homeownership falls by about 16 percentage points over 1995–2019 (blue line). With mortgage down-payments held constant at their 1995 levels for the duration of the simulation, under-40 homeownership falls by 12 percentage points (orange line). When we calculate stamp duty using 1995 house values for the duration of the simulation, the under-40 homeownership rate falls by around 11 percentage points (green line). Thus, the model suggests that rising mortgage down-payments, and the rise in stamp duty that is directly attributable to a higher house price-income ratio, both explain around one quarter of the fall in under-40 homeownership. The effects of these channels appear close to additive in the model. When we switch both of them off, under-40 homeownership declines by around 8 percentage points (red line). Finally, when we keep down-payments and stamp duty fixed at 1995 levels, by additionally keeping the stamp duty schedule at its 1995 location in Figure 3, under-40 homeownership declines by only 5 percentage points (purple line).[11]

[10] This can be thought of as a counterfactual in which stamp duty schedules were indexed to the aggregate house-price income ratio.

[11] We suspect this remaining decline in under-40 homeownership is due to younger households in the

To summarise, the main result of our decomposition is that rising mortgage down-payments, and the rising stamp duty brought about by higher house price-income ratios both individually explain around one quarter of the decline in the under-40 homeownership rate in the model. That is, our model suggests that rising stamp duty is quantitatively just as important as rising mortgage down-payments for explaining the decline in under-40 homeownership over 1995–2019. This might seem surprising given that the 15 per cent down-payment is much larger as a proportion of income than stamp duty. However, mortgage down-payments are eventually recouped by mortgagors, while stamp duty is a pure *cost* from the perspective of purchasers in our model. This cost rises over time in our simulations, and is not offset by lower taxes elsewhere.[12]

4.4. The intensive margin of housing

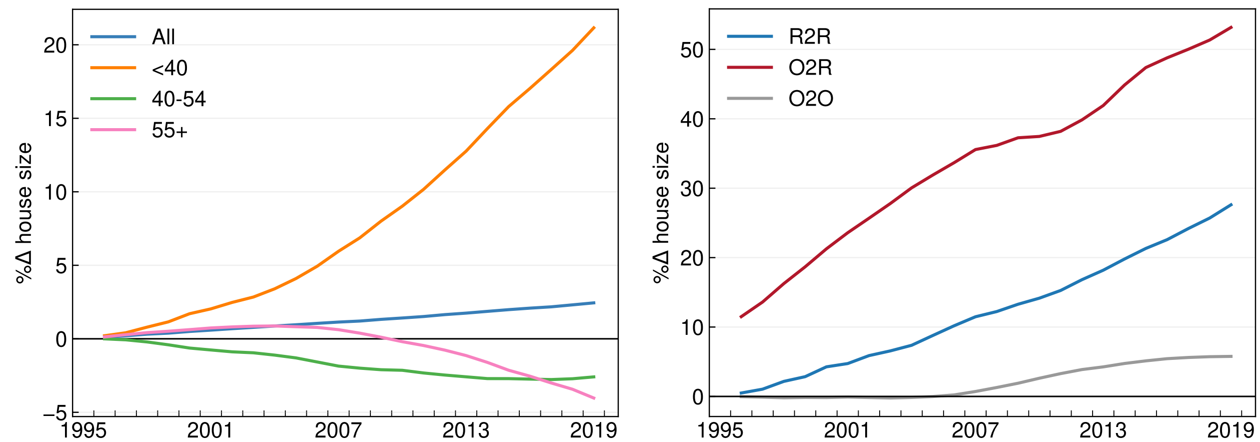
Comparing the consumption of housing services by age and tenure along the transition path can help us understand the mechanisms in the model. The average dwelling size increases over the course of the transition in line with the effect of increased demand on supply (recall, here we are allowing the supply curve of housing services to be upward sloping with an elasticity $\vartheta = 0.07$). Within that average increase, we see a large increase in the average amount of housing services consumed by younger households, and small declines in older households (Figure 10(a)).

The greater consumption of housing by young households may appear surprising given younger households face more difficult buying conditions. The mechanism in play however, can be understood as young renters delaying or abandoning the transition from an optimally sized rental property to a down-payment/transaction cost constrained owned house that is smaller than they would prefer to live in. To see this, note that when we simulate households in the transition we keep the cross-section of initial liquid wealth, income, and taste shocks, exactly the same in each period. That is, we draw a vector of N_{sim} initial liquid asset positions, and $N_{sim} \times J$ arrays of idiosyncratic income shocks and taste shocks to simulate N_{sim} households in the initial steady state. We repeat these cross-sections of initial liquid

model choosing to consume more housing services as interest rates fall, which we discuss in section 4.4.

[12]We illustrate this point in Figure 13. In it we consider a version of the model with a flat-rate stamp duty set at 2.5 per cent of the purchase price. We re-do the benchmark simulation. We then run partial-equilibrium versions of the simulation by feeding in the price and rent paths from this flat-rate benchmark simulation, while separately: (a) switching-off rising stamp duty; and (b) allowing households to borrow at the mortgage rate to pay any additional stamp duty relative to what they would've paid in 1995. Allowing households to borrow the additional stamp duty barely affects the decline in under-40 homeownership. Switching-off rising stamp duty altogether produces a 25 per cent smaller decline, as in our benchmark decomposition above. This exercise confirms that it is not the upfront nature of stamp duty that leads to lower homeownership as prices rise, but rather that it is a cost associated with homeownership that rises with house prices.

Figure 10: Change in House Size Along the Transition



A. By age group **B.** By tenure category

Notes: In panel B, R2R refers to households who are are renters in year t, and who, *given the same initial liquid wealth, and paths of income and taste shocks*, would have been a renter in the 1995 steady state. O2O refers to households who own in year t, and would have owned in the 1995 steady state. O2R refers to households who rent in year t, but would have owned in the 1995 steady state.

Sources: Authors' computations.

wealth, income shocks and taste shocks in each period. This means that in any period of the transition t, we can pick out some age-j household, and compare them to an age-j household in the initial steady state who experiend the *exact* same path of idiosyncratic income and taste shocks upto age-j, and who entered the model with the same level of initial liquid wealth. With this structure in mind, the owner-to-renter (O2R) line on Figure 10(b) refers to are households that under 1995 prices and interest rates would have owned (given their initial liquid wealth, path of income, and taste shocks) but facing period-t prices and interest rates choose to rent. These O2R households, not being constrained by mortgage down-payments or transaction costs as renters, consume roughly 10 per cent more housing even at the start of the transition. As the transition continues all renters (i.e. O2R and R2R households) increase their housing consumption as rents fall. It is worth noting here that our model has no concept of location, and house size is the only dimension of value. A young household renting a small inner urban apartment is implicitly mapped to more consumption of housing than the same household buying a physically larger, but cheaper, house in a less expensive location.

5. Conclusions

We build a life-cycle heterogeneous-agent model of the Australian housing market to study the effect of declining interest rates on homeownership rates across the age spectrum. As rates decline, house prices rise, which tightens the down-payment constraint on new mortgages and raises transaction costs of buying housing. Homeownership falls. Our model suggests that the effect of lower rates on homeownership is quantitatively large and explains the observed decline in homeownership rates across the age spectrum. The tightening effect of higher minimum mortgage down-payments and the effect of higher stamp duty costs contribute roughly equally to fall in homeownership in the model.

Our model has has several limitations. We list a few here, along with ideas for future work. First, as mentioned, house size or quality is the only dimension of a house's value in our model. Incorporating a meaningful location choice seems promising. With that, one could study how higher house prices brought about by lower rates has affected not only homeownership rates, but also households' spatial sorting. Second, for tractability we adopt a simple, and extreme, assumption about what households' expect about the future. We think a deeper exploration of different expectation formation processes, such as adaptive learning, extrapolative, or diagnostic-type expectations, would be worthwhile in the context of declining interest rates and higher prices. And finally, our model implicitly assumes that the rental stock is owned by deep-pocketed, foreign-owned landlords. In reality the rental stock in Australia is mostly owned by households. Capital gains on rental housing could be an important source of wealth accumulation for wealthier households. Extending our setup to allow for household-landlords and intergenerational transfers would be challenging but could provide a useful laboratory for thinking about the intergenerational transmission of housing wealth and inequality.

A. Additional model details

A.1. Age-J problem

The renter's age-J problem is

$$V_J^{\text{rent}}(\tilde{x}) = \max_{c,s} u(c,s) + u^B(q')$$

$$\text{s.t.}$$

$$c + a' + p^r s = \tilde{x}$$

$$s \in S$$

$$q' = a'$$

The buyer's age-J problem is

$$V_J^{\text{buy}}(\tilde{x}) = \max_{c,h'} u(c,h') + u^B(q')$$

$$\text{s.t.}$$

$$c + a' + \delta h' = \tilde{x} - p_t^h h' - SD_t(p_t^h h')$$

$$h' \in H$$

$$q' = a' + p_t^h h'$$

Finally, the stayer's age-J problem is

$$V_J^{\text{stay}}(h,m,x) = \max_{c} u(c,h) + u^B(q')$$

$$\text{s.t.}$$

$$c + a' + \delta h + (1 + r_{t-1}^m)m = x$$

$$q' = a' + p_t^h h$$

A.2. Analyitical forms of the value function and choice probabilities

The inclusion of taste shocks implies that discrete choices are probabilistic. And because we use the canonical iid EV-1 distribution, the expected value function has the well-know log-sum formula:

$$\mathbb{V}_{j+1}(z',h',m',x') = \sigma_\xi \log\left(\sum_{k\in K} \exp\left(\frac{V_{j+1}^k(z',h',m',x')}{\sigma_\xi}\right)\right) \tag{17}$$

where $K = \{\text{rent}, \text{buy}, \text{stay}, \text{refi}\}$ is the set of discrete choices available to households. The logit choice probabilities are:

$$P(k|z,h,m,x) = \exp\left(\frac{V_j^k(z,h,m,x)}{\sigma_\xi}\right) \Big/ \sum_{k \in K} \exp\left(\frac{V_j^k(z,h,m,x)}{\sigma_\xi}\right). \tag{18}$$

B. No taste shock calibration

Table 3: Fitted Parameters and Moments – No Taste Shock

Parameter	Description	Value	Target moment	Model	Data
β	Discount factor	0.94	Mean LTV of homeowners	0.18	0.17
α	Non-durable share in utility	0.82	Median house value/mean income	2.40	2.38
B	Bequest motive	17.73	Median NW 65-74/median NW 75+	1.29	1.28
$\underline{h}$	Smallest ownable house size	2.8	Homeownership rate	0.79	0.71
ϕ	Rent wedge	0.03	Homeownership rate < 40	0.56	0.60

C. Computation

C.1. Solution method

We solve the household's problem using the nested endogenous grid method (NEGM) outlined by Jeppe Druedahl, and adapt his Python implementation. The general idea is to use EGM to solve the renter and stayer's problems in a first step. Druedahl introduces an upper envelope algorithm to deal with the fact that non-convexities in the household's problem make the Euler equation necessary but not sufficient for a solution. In a second ('nesting') step, we solve the buyer and refinancer's problems by using the already-computed solution to the stayer's problem, with an appropriate adjustment to cash-on-hand. Below, we illustrate how this nesting structure works in the case of a buyer.

First define an auxiliary debt variable m. Conditional on a choice of house size h' and debt $m' = (1 + r^m_{t-1})m - \pi_j(m)$, we can write a buyer's consumption-saving problem as:

$$\begin{aligned} V_j^{\text{buy}}(z, \tilde{x}; h', m') &= \max_c u(c, h') + \beta \mathbb{E}_t[\mathbb{V}_{j+1}(z', h', m', x')] \\ &\text{s.t.} \\ c + a' + \delta h' &= \tilde{x} - p^h h' - SD(p^h h') + (1 + r^m_{t-1})m - \pi_j(m) \\ m' &= (1 + r^m_{t-1})m - \pi_j(m) \end{aligned}$$

This consumption-savings problem is exactly the same as the stayer's problem (8) just with an appropriate adjustment to the level of cash-on-hand. Define an adjusted cash-on-hand variable x^{buy} as

$$x^{buy}(m) = \tilde{x} - p^h h' - SD(p^h h') + (1 + r^m_{t-1})m.$$

Then conditional on a choice of house size h' the buyer's problem is now:

$$V_j^{\text{buy}}(z, \tilde{x}; h') = \max_{m \leq M} V_j^{\text{stay}}(z, h', m, x^{buy}(m))$$

where M is defined by the LTV and PTI constraints, and which we derive next. Let $A_{jt} = \frac{r^m_{t-1}(1+r^m_{t-1})^{J-j}}{(1+r^m_{t-1})^{J-j}-1}$. Then:

$$m' = (1 + r^m_{t-1})m - A_{jt}m = (1 + r^m_{t-1} - A_{jt})m$$

And

$$\pi_{j+1}(m') = A_{j+1,t+1}m' = A_{j+1,t+1}(1 + r^m_t - A_{jt})m$$

The LTV limit is:

$$\begin{aligned} m' &\leq \theta^{LTV} p^h_t h' \\ \implies (1 + r^m_{t-1} - A_{jt})m &\leq \theta^{LTV} p^h_t h' \\ \implies m &\leq \theta^{LTV} p^h_t h' / (1 + r^m_{t-1} - A_{jt}) \end{aligned}$$

And the PTI limit is

$$\begin{aligned} \pi_{j+1}(m') &\leq \theta^{PTI} z \\ \implies A_{j+1,t+1}(1 + r^m_{t-1} - A_{jt})m &\leq \theta^{PTI} z \\ \implies m &\leq \theta^{PTI} z / [A_{j+1,t+1}(1 + r^m_{t-1} - A_{jt})] \end{aligned}$$

Thus $M = \min\left\{\frac{\theta^{LTV} p^h_t h'}{(1+r^m_{t-1}-A_{jt})}, \frac{\theta^{PTI} z}{A_{j+1,t+1}(1+r^m_{t-1}-A_{jt})}\right\}$.

Putting this altogether, nesting implies that solution to the buyer's problem is:

$$V_j^{\text{buy}}(z, \tilde{x}) = \max_{h' \in H} \left\{ \max_{m \leq M} V_j^{\text{stay}}(z, h', m, x^{buy}(m)) \right\}$$

$$\text{where: } M = \min\left\{ \frac{\theta^{LTV} p^h_t h'}{(1 + r^m_{t-1} - A_{jt})}, \frac{\theta^{PTI} z}{A_{j+1,t+1}(1 + r^m_{t-1} - A_{jt})} \right\}$$

Let $m^*(z,\tilde{x})$ be the solution to this problem for the auxiliary debt variable. The actual policy function for mortgage debt $m'^*(z,\tilde{x})$ is

$$m'^*(z,\tilde{x}) = (1 + r^m_{t-1} - A_{jt})m^*(z,\tilde{x})$$

We use a very similar procedure to solve the refinancer's problem.

C.2. Grids

We discretise the household's problem using grids for the random walk component of income w, house size h, and cash-on-hand variables x and $\tilde{x}$. As is standard in quantitative housing models similar to ours, we use a grid for loan-to-value ratio rather than mortgage size m; beginning-of-period mortgage debt can be easily derived using the formula: $m = ltv \times p^h_t \times h$. We use 10 grid points for w, 10 for house size h (which includes $h = 0$), 20 for loan-to-value ratio, and 50 for the cash-on-hand variables. The rental house size grid S has 15 points. NEGM also requires grids for post-decision state variables. In our model these are owned house size h', mortgage size m', and liquid wealth a'. We use 50 grid points for a'. We allow policy functions for non-durable consumption c, liquid wealth a' and loan-to-value ratio to be off-grid using linear interpolation. We approximate the transitory and permanent income shocks using 5 Gauss-Hermite quadrature nodes for each. The linear interpolation and quadrature algorithms come from Jeppe Druedahl's excellent ConSav Python package.

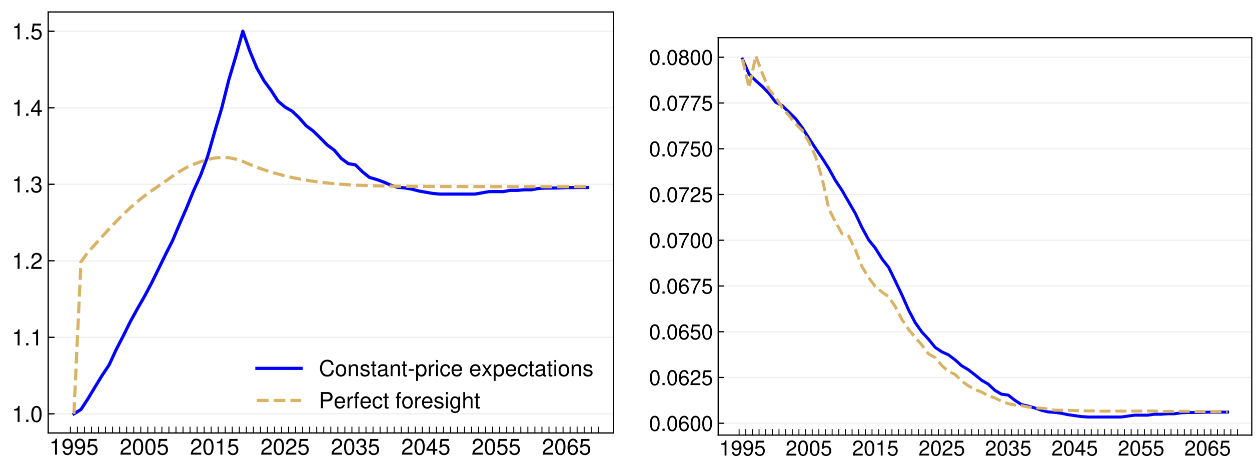
C.3. Simulating households

When solving for equilibrium we simulate $N = 100,000$ households for J periods. Let $i \in \{1, ..., N\}$ be a household's 'id' number. A household at a point-in-time can be indexed by their id, their age, and the time period (i, j, t), where $t = 0$ corresponds to the initial steady state. Prior to simulating decisions, we pre-draw $N \times J$ values from a $U[0, 1]$ distribution. We use these random numbers to determine households' discrete choices, which are drawn from discrete distributions characterised by the choice probabilities (18). We also pre-draw $N \times J$ realisations of the permanent and transitory income shocks. We keep the $N \times J \times 3$ realisations of these shocks constant throughout our transition experiments. This means we can usefully compare household (i, j, t) to household $(i, j, 0)$ in the initial steady state, with both experiencing the same realisations of taste and income shocks over their lives.

Households enter the model at age $j = 1$. In the initial steady state, these newborn households draw their starting liquid wealth a_0 from the calibrated distribution. They also draw an initial random walk component of income w_0. During the transition experiments, newborns draw their starting liquid wealth according to $a_0(i,1,t) = a_0(i,1,0) + \frac{a_0(i,1,0)}{\sum_n^N a_0(n,1,0)} \times (BQ_t - \bar{BQ})$, where BQ_t are bequests collected from age-J agents in period $t-1$, and $\bar{BQ}$ are bequests collected in the initial steady state.

D. Additional model results

Figure 11: Perfect Foresight vs. Constant-Price Expectations

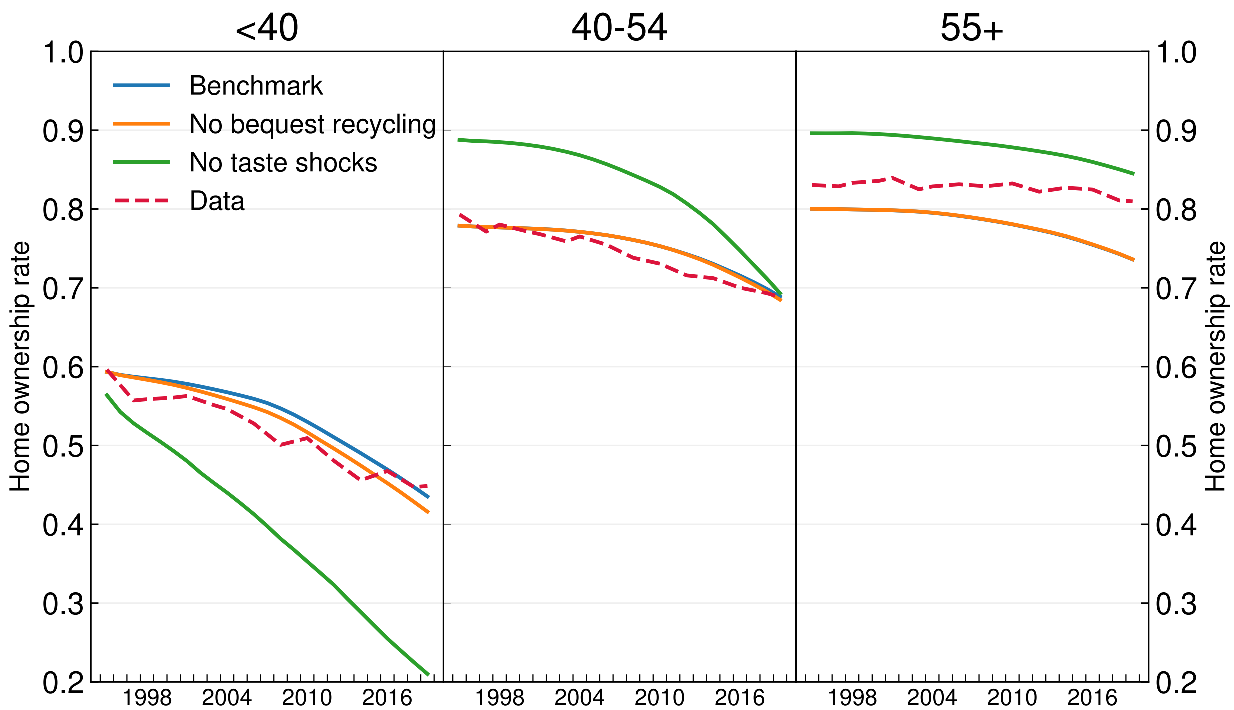


A. House price p_t^h **B.** Rental rate p_t^r

Notes: This figure shows the model house price (panel (a)) and rental rate (panel (b)) under constant-price expectations, and perfect foresight. For these simulations we use $\vartheta = 0$, and apply a 3 percentage point interest rate decline over 1995–2019; for 2019 on interest rates are held constant.

Sources: Authors' computations.

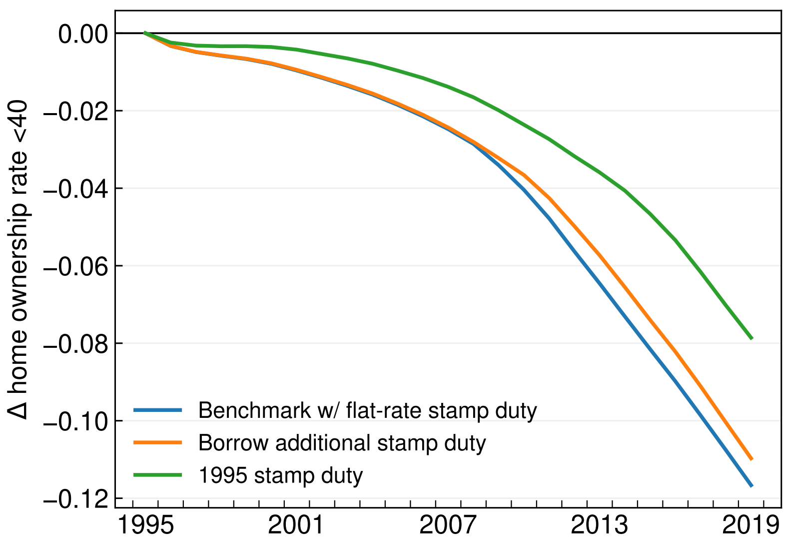
Figure 12: Homeownership Rates by Age Group in Different Versions of the Model



Notes: Homeownership data are from the 1994/5–2019/20 waves of the SIH. For the benchmark model results we apply a 3 percentage point interest rate decline over 1995–2019, and use a housing supply elasticity $\vartheta = 0.07$. No bequest recycling does not distribute excess bequests relative to the 1995 steady state to newborn households. No taste shock uses the no taste shock calibration.

Sources: ABS; Authors' computations.

Figure 13: Decline in Homeownership Among Under-40s When Households Can Borrow Any Increase in Stamp Duty



Notes: This figure shows the decline in under-40 homeownership in a version of the model with a flat-rate stamp duty set to 2.5 per cent of the purchase price, along with two counterfactuals: one where households can borrow at the mortgage rate to pay any additional stamp duty relative to 1995, and one where rising stamp duty is switched-off during the transition.

Sources: Authors' computations.

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