Old Age Savings and House Price Shocks

Rory M\textsuperscript{c}Gee\textsuperscript{*}

November 9, 2021

First Version: August, 2019

Abstract

Elderly households hold most of their wealth in housing, maintain high levels of wealth throughout retirement, and often leave bequests. The value of their houses are subject to large shocks. To what extent do these shocks affect their savings, consumption, and bequests? Answering this question requires separating precautionary savings, bequest motives, and the desire to remain in one’s home. I develop and estimate a structural model of retirement savings decisions with realistic risks, housing, and heterogeneity in bequest preferences. I exploit policy changes to the taxation of housing and bequests to separately identify the different motives for holding wealth. Estimates show approximately half of retirees have no bequest motive. House price changes are quantitatively important, with 1/4 of increases passed on to future generations. I use the estimated model to evaluate means-tested programs insuring retirees’ LTC expenses. I find exemptions providing marginal liquidity have larger insurance value than fully eliminating LTC expense risk per pound it costs the government.

\textsuperscript{*}University of Western Ontario and Institute for Fiscal Studies, rmcgee4@uwo.ca. This paper was previously circulated under the title “Savings after Retirement: Homeownership, Preferences or Risks?”. I thank Mariacristina De Nardi and Eric French for invaluable guidance as well as Richard Blundell, Gabriella Conti, Arpit Gupta, John Bailey Jones, Hamish Low, Joseph Mullins, Cormac O’Dea, Gonzalo Paz-Pardo, Michela Tincani and numerous seminar participants for helpful comments and discussion.
1 Introduction

In the last quarter century, the OECD’s over 65 population has grown by more than 40% and is projected to increase further. These older households hold lots of wealth, even at advanced ages, and often leave bequests. Most of this wealth is in the form of houses, which exposes elderly households, with relatively short planning horizons, to significant house price risk. Furthermore, houses provide a consumption flow, are illiquid, and are often exempt from tests on assets that determine eligibility for important government insurance programs.

This paper aims to understand the connections between household portfolios, savings, and expenditure decisions in old age, taking into account the role of bequests and long term care (LTC) risks. I use the response of household consumption and savings to house price shocks and liquid wealth shocks to understand the different role played by these assets. I use evidence from a natural experiment affecting the returns to liquidating housing to inform a rich structural model of household decisions. With the model I evaluate the welfare implications of governmental LTC insurance programs, which frequently include exemptions for housing wealth.

To uncover the importance of retiree responses to changing financial incentives to liquidate housing, I examine behaviour around thresholds in the tax system. In particular, I exploit discontinuous increases in the Average Tax Rate (ATR) levied on housing transactions in the UK using data from the English Longitudinal Study of Aging. I examine how retirees adjust the housing component of their portfolio when the financial incentives differ on either side of this discontinuity. I argue small changes in the ATR generate large implicit taxes on extracting home equity by downsizing.

Next, I show that in response to a £5,000 increase in the tax burden on their property retirees halve their probability of selling in the next two years - an almost 3 percentage point reduction. Additional analysis of moving decisions shows a minority of retirees move to renting and a majority remain homeowners after selling their current house. These empirical results are inconsistent with the hypothesis that housing equity is trapped or held passively in retirement. Instead, all else equal, retirees are more likely to downsize as prices rise and cash out housing windfalls.

As houses are complex assets affecting incentives through multiple channels, I explore this mechanism further using a dynamic structural model in which retirees choose between investing in housing, risk-free liquid wealth, or consuming today. To
correctly determine households’ desire for liquidity, consumption, and savings for bequests over different horizons, and consequently their demand for different assets I incorporate a rich set of risks, including aggregate risks, and preference heterogeneity between households. Separately identifying precautionary savings motives, the desire to remain in one’s home, and a bequest motive when there are many reasons households may hold wealth presents a considerable empirical challenge even when preferences are homogenous.\textsuperscript{1} To identify preferences for housing and its illiquidity separately from other savings motives, I exploit longitudinal variation in both housing transaction and estate taxes as well as UK house prices. I match moments on wealth composition, moving house and a measure of subjective expectations across multiple policy regimes using the method of simulated moments.

I validate the estimated model by estimating the response to discontinuous increases in the transaction tax ATR in simulated data - moments intentionally excluded in estimation. The model matches the magnitude of retirees’ responses to changes in the financial incentive for moving house and other key facts on the evolution of household portfolios included as targets. Estimated parameters reveal retirees value the independence associated with remaining a homeowner and they incur considerable costs when moving house. In addition, there is important dispersion in the desire to leave a bequest which is correlated with saving before retirement.

Armed with the carefully estimated model matching these and other important facts, I quantify responses to changes in different sources of retirement wealth. UK house prices more than doubled in the last 30 years. To what extent are these windfalls shared with younger generations? On average, only a quarter of house price shocks experienced at age 70 are passed on to future generations as bequests. In contrast, 40\% of liquid wealth shocks are passed on. The key mechanism driving this disparity is the opposite effects on liquidity constraint from increasing in house prices and liquid wealth. For retirees with little liquid wealth, house price increases make downsizing more attractive as they have more cash to spend after the sale. Injecting the same of money into their bank account lowers the probability of downsizing because they have more resources to spend today without needing to sell their house. This generates large differences in aggregate downsizing behaviour and realized bequests.

I use the estimated model to examine the design of means-testing LTC benefits for retirees’ well-being. The UK government is payer of last resort for LTC expenditures,

\textsuperscript{1}See, for instance, De Nardi et al. (2010); Ameriks et al. (2020); Lockwood (2018).
requiring retirees first spend down their private resources. In practice, differences in how resources are assigned across spouses exempts the housing wealth of couples from this requirement. Taking the current eligibility rules as given, I simulate retirees through a set of counterfactual reforms eliminating differences across asset classes. For each pound the government spends, I find providing exemptions on just liquid wealth deliver 75% of the benefits from exempting combined housing and liquid wealth. Crucially, exempting only housing wealth does not provide enough liquidity to keep healthy spouses in their homes. When retirees place a high value on their illiquid housing, the value of providing marginal liquidity through exemptions is high.

**Related Literature** This paper makes three contributions. First, I develop and estimate a dynamic life cycle model including precautionary saving, heterogeneous bequest motives and a rich model of housing choice. To estimate different savings motives in retirement, I combine self-reported probabilities of leaving an inheritance (a widely available survey instrument) with data on portfolios and quasi-experimental variation in tax schedules. This compliments the instrumental variable approach proposed by Lee and Tan (2019). Ameriks et al. (2020) instead combine panel data on financial wealth with hypothetical choice experiments from bespoke strategic survey questions on bequests and long term care. Inkmann and Michaelides (2012), De Nardi et al. (2016a), and Lockwood (2018) estimate quantitatively important bequest motives to rationalize insurance under-utilization (life insurance, Medicaid take-up and LTC insurance respectively). The allocation of wealth across assets with different self-insurance capacities provides similar information on precautionary motives and provides a potential alternative explanation for this underutilization.

Second, I document the importance of housing wealth and downsizing decisions in retirement. This is closely related to studies of housing demand at younger ages, for instance Cocco (2005) and Attanasio et al. (2012), and portfolio choice in retirement, including Yogo (2016). Nakajima and Telyukova (2020) and Cocco and Lopes (2020)

---

2As with Medicaid coverage in the US, eligibility is determined by both income and wealth. This imposes a 100% marginal tax on both savings and income above eligibility thresholds.

3Several studies explore the role of idiosyncratic risk in old age with Hurd (1989) suggesting mortality risk is the primary empirical driver of savings in retirement or, as in Palumbo (1999), medical expenses faced by retired households are necessary to explain their limited deaccumulation. Studies in this tradition argue risk averse households maintain wealth and exhibit slow deaccumulation because of high levels of precautionary savings and that bequests are accidental. De Nardi et al. (2010) find longevity and medical expenditure risk dominate for singles, while De Nardi et al. (2021) find bequest motives are important for couples. De Nardi et al. (2016b) survey this literature.
have the closest asset structure to the model in this paper among studies of retirees. Both model retirees’ decisions to remain in their own home and how this dampens the use of reverse mortgage loans. I focus on the intensive and extensive margin of downsizing as a means of home equity extraction, presenting novel causal evidence on its response to financial incentives embedded in the tax system. I calculate the welfare effects of, hitherto little studied, differential means-testing across asset classes. In contemporaneous work, Achou (2020) studies the welfare effects of Medicaid’s homestead exemption on single US retirees focusing on medical spending and the homeownership decision. I study a similar policy for married UK retirees as well as exemptions on their liquid wealth. I show how these policies affect marginal liquidity and welfare. Additionally, couples who are a large share of the elderly, are more likely to own houses and hold more wealth at all ages.

Third, this study illustrates the implications of rising house prices for the savings and consumption behaviour of retirees. Rising house prices may lead to larger bequests if retirees retain housing wealth. Alternatively, they may offset increases by spending part of their windfall. This paper investigates how different windfalls affect consumption expenditures in retirement and the intergenerational transmission of wealth. Early attempts to understand the effect of house price changes on the consumption and savings decisions of retirees include Skinner (1996). His work emphasises how economizing on housing services by downsizing may offer an alternative way to self-insure, but that large fractions of housing wealth may be bequeathed. This work builds on similar insights by adding theoretical structure using a life cycle framework and detailed micro data on wealth, health, and choices from a panel of retirees. I quantify the housing wealth effect on both consumption and bequests comparing it with the effect of pension windfalls. Lockwood (2018) argues bequests are more subject to substitution than own consumption. Consequently, retirees cut back the relative luxury of bequests when they need resources, rather than cut consumption (Browning and Crossley, 2000). The fungibility of savings for bequests lowers the opportunity cost of self-insurance and demand for formal insurance. Here I focus on how this greater substitution affects consumption out of housing wealth.

Incorporating heterogeneous bequest motives allows me to document important

---

4 An increase in household expenditures in response to an increase in home values. An inexhaustive list of recent contributions focusing on those using micro data include Mian et al. (2013); Kaplan et al. (2020); Aladangady (2017); Berger et al. (2018); Guren et al. (2021).
variation in responses to windfalls. Hurd (1989) models binary heterogeneity by assuming no bequest motive for the childless. My approach is closer to the finite-mixture estimation in Kopczuk and Lupton (2007), relying on a classification procedure to reduce the dimensionality and retain tractability. I allow for more flexibility in parameterizing bequest motives and distinguish preference heterogeneity from differences in portfolios. Ameriks et al. (2018) allow for idiosyncratic bequest motives estimated using strategic survey questions, but focus only on the financial component of household portfolios. Understanding windfall responses is an important step in understanding housing’s role in financing retirement and the adequacy of individual’s nest eggs for retirement. Both Scholz et al. (2006) and Gomes et al. (2020) study this question under different assumptions about the draw down of housing in retirement.

2 Data & Key Facts

The English Longitudinal Study of aging (ELSA) began in 2002/03, it is a biennial survey modeled on the US Health and Retirement Study (HRS) containing a representative sample of the non-institutionalized English population aged 50+. It collects detailed panel data on demographics, earnings, health, wealth and portfolios using face to face interviews and supplementary questionnaires.

I use data from the first 7 waves and present statistics for within group means for each five year birth cohort and, as discussed below, stratified by additional data. To abstract from labour decisions around retirement, I keep a subsample of households where the head is above the age of 65 (the state pension age for men) and who do not participate in the labour market.\(^5\) Consistent with the model, I drop households when either a new individual enters or leaves the household before death - this drops all households who either divorce or remarry during the sample period, but includes the newly widowed. I top-code wealth moments at the within group 95th percentile and drop cells with fewer than 15 observations to mitigate the impact of outliers. As a cohort ages, it is increasingly comprised of rich people due to mortality differences between the rich and poor. To mitigate composition effects, I present wealth trajectories grouped by Permanent Income (PI) quantiles.\(^6\) This controls for

\(^5\)I define non-participation as households with labour income below pension credit levels, a means-tested benefit which tops up household income for those out of work and eligible for state pensions.

\(^6\)Attanasio and Emmerson (2003) document this composition bias in the UK. Results using a balanced panel for those surviving from the first wave until the final wave are similar, but impose
the lifetime income levels of the households. To calculate PI I follow the approach in De Nardi et al. (2021) and exploit the approximately monotonic relationship between lifetime resources and pension income in the UK. I sum all sources of annuity income in retirement and regress this measure on a polynomial in age interacted with family composition and a fixed effect. I take the percentile rank of the fixed effect as an estimate of each household’s PI - a measure invariant to household demographics. Appendix A provides more details. For clarity, I present results for three birth cohorts in the main text: those born between 1915 and 1919, 1925 and 1929, and 1935 and 1939. Results for remaining cohorts are shown in Appendix B.

I generate three PI groups: the top 25% of households, the second quartile, and the bottom 50% of households. I separate households by PI, cohort, and by their initial homeownership status to additionally control for housing tenure. I define initial homeownership in the first wave a household enters the sample and this definition keeps the composition of each group constant in the analysis. Although there are differences in initial homeownership rates, I group the bottom two PI quartiles as conditional wealth holdings are extremely similar. For renters, I do not stratify by PI as they are largely drawn from the bottom 50% of the PI distribution.

To explore savings in different forms of wealth I present results for housing and non-housing wealth. Housing wealth is the value of their primary residence. Mortgage debt and other property is included in liquid wealth - for retirees these balances are small. Liquid (or non-housing) wealth also includes savings and current accounts, bonds/gilts, premium bonds, shares, trusts, and other physical assets less credit card debt, private debt and any other outstanding loans or debts.7

2.1 Housing Wealth

Savings in retirement differ by PI and a large share of this heterogeneity is driven by differences in housing wealth. The left panel of Figure 1 shows the mean housing wealth of households and the right panel shows the frequency with which initial homeowners move properties over a two year period (the frequency of the ELSA data). There is a strong PI gradient for housing wealth even after conditioning on initial home ownership status. Focussing on the 1925-1929 birth cohort (dashed lines), much stricter selection requirements while ignoring the important role of mortality risk at older ages.

7Savings accounts include TESSA, all forms of ISA, PEPs, National Savings Accounts and life insurance savings. I drop retirees who directly own businesses.
owners in the top quartile hold on average £275,000 in housing wealth at age 77. Those in the second quartile hold only £200,000 and those initial owners in the bottom half of the PI distribution have an average of £165,000 in housing wealth at age 77. Both absolute and relative differences increase with PI. While these differences vary across cohorts and as cohorts age there remain large differences between PI groups.

One striking feature of the UK data is the presence of time effects, which have been little studied in the context of the US or other countries. For all cohorts and PI groups, housing wealth displays evidence of an aggregate trend. The x-axis plots the average age within birth cohort - thus, within cohort aging is equivalent to plotting a time dimension. Figure 2 plots the evolution of house prices over the previous 30 years. While broadly increasing, there is a clear correlation between their trend and the housing wealth of retirees. In Figure 1a mean housing wealth increases by £75,000 between ages 77 and 81 for retirees in the second PI quartile and the 1925-29 birth cohort. Between 81 and 83 these same households see almost 40% of this gain reversed and gradual declines through the rest of the sample as house prices fall in the wake of the great recession. Similar patterns are clear at different PI levels and ages, but at the same points in calendar time.

The rise and subsequent fall in housing wealth differs across PI and birth cohort

---

8 As noted in Schulhofer-Wohl (2018) many studies attempt to cleanse time effects from estimation moments in the data. As housing wealth is almost 70% of retirees’ aggregate wealth, total wealth displays similar time effects inheriting this trend over the sample (see Appendix B).
Quarterly real house prices over time, relative to 1990 Quarter 1. The red line plots data for the UK and the green dashed line plots data for the US. The dashed blue line plots within quarter averages for OECD member countries. Source: OECD Housing Prices Indicator (2021)

in part due to differences in moving house or cashing out behaviour. However, in the aggregate, evidence of deaccumulation is limited. Average housing wealth increases between the start and the end of the sample for all cohort and PI combinations as prices appreciate, masking downsizing behaviour.

To understand the economic importance of household mobility and to distinguish passive saving from active portfolio rebalancing of older households, I focus on the frequency and size of decisions to adjust housing wealth. Figure 1b shows limited age and cohort variation with an average of 4.4% of households selling their house and moving each wave. These adjustments are infrequent with those over 65 moving only once on average. Nevertheless, almost 50% of households move by age 90.

Moving house is one of the largest financial decisions during retirement. Adjustments are large and households can realise gains from changes in house prices. Table 1 provides statistics on the mean level and relative change in housing wealth for three different categories: all downsizers, those who downsize and remain owner occupiers, and those who upsize. Within downsizers, who are over 75% of movers, I separate out transitions to renting to control for changes in the extensive margin of ownership. Conditional on downsizing, the average household releases 52% of the current value of their house or over £135,000. This is not driven by only the extensive margin as downsizers who remain owner occupiers release over £100,000 of equity. This is
Table 1: Average Housing Wealth Change by Move Type

<table>
<thead>
<tr>
<th>Move Type</th>
<th>Change in Housing Wealth</th>
<th>Relative Change</th>
<th>Proportion of Movers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downsizers (All)</td>
<td>-136</td>
<td>0.48</td>
<td>76.8</td>
</tr>
<tr>
<td>Downsizers Remaining Owners</td>
<td>-104</td>
<td>0.72</td>
<td>50.9</td>
</tr>
<tr>
<td>Upsizers (All)</td>
<td>55.4</td>
<td>1.34</td>
<td>23.2</td>
</tr>
</tbody>
</table>

Source: Author’s own calculation from ELSA using a sample of 430 movers. All columns report means. a £1000s in 2014 prices, b Relative change is defined as the ratio of the new price to the old price at time of sale.

approximately 40% of the average total wealth level or 30% of their previous housing wealth. The majority of retirees climb only a few rungs back down the housing ladder, remaining homeowners even at advanced ages. Upsizers are the smallest group, but they make large adjustments - increasing their housing wealth by a third.

On aggregate retirees retain capital gains in housing and house price changes affect different birth cohorts at different ages. However, those moving house make large adjustments to their portfolio and many retirees move during their retirement. Housing is a store of wealth that may appreciate or decline in value, provides a consumption flow and is subject to potentially large adjustment costs. Explicitly modeling these assets is important for understanding saving during retirement, demand for self-insurance, and the extent to which price changes improve financial security.

2.2 Liquid Wealth

Figure 3 displays average liquid wealth for the same groupings of initial owners on the left. While differences between the bottom half of the PI distribution and the second quartile are of similar magnitude to the absolute gap in housing wealth they are larger in relative terms. The gap between the liquid wealth of the top quartile and the second PI quartile is slightly larger than in housing wealth at almost £100,000 for each age and cohort pair. This is because, on average, housing wealth is a smaller proportion of the portfolio of richer households.

Unlike housing wealth, there is no strong evidence of cyclicality in liquid wealth. Furthermore, within each cohort-PI group there is some evidence of deaccumulation. For the youngest two cohorts, liquid wealth in the top PI quartile falls by over £45,000.
(a) Initial Owners 

(b) Initial Renters

Figure 3: Mean Liquid Wealth by Cohort (ELSA data)

Panel (a): Each line shows a cohort-PI cell over the period 2002-2014, plotted against average cohort ages. Thicker lines denote higher PI groups. Panel (b): cohort cells for the same period.

(from £189,000 at age 67 to £148,000 by 79 and £184,000 at age 77 to £137,000 by 89) and by over £20,000 (from £81,000 at age 67 to £55,000 and £70,000 at age 77 to £47,000) for the second PI quartile. For the lowest PI group, the youngest cohort show modest accumulation between ages 67 and 79, but deaccumulation of a similar magnitude to the second PI quartile for the 1925-29 birth cohort.9

Finally, I turn to the liquid wealth of initial renters. In retirement, initial renters tend to belong to lower PI percentiles. Thus, I pool all renters together. On average, initial renters hold less than half the liquid wealth of their counterparts in the bottom PI homeowners. They are both cash and income poor. While their wealth varies between £5,000 to £20,000 for different age and cohort combinations it is approximately stable. In contrast, the savings of US retirees transitioning from owning to renting decline (Nakajima and Telyukova, 2020).

For owners, increasing housing wealth offsets modest deaccumulation of liquid wealth. Blundell et al. (2016) document price-driven housing wealth increases in the UK in contrast to US evidence from the HRS. While US evidence typically finds more deaccumulation among elderly singles, Poterba et al. (2018) document a high degree of persistence between early retirement wealth and wealth at death. In the US, medical costs, longevity risk, bequests, and homeownership are important for explaining this departure from the life cycle hypothesis. The results above highlight saving in

9While there are some increases at the oldest ages, these cells tend to have fewer observations and are, thus, noisier measurements.
different assets and the interaction with asset price movements is an important part of retirees’ financial behaviour and, consequently, the ‘retirement savings puzzle’.

3 Variation in Tax Incentives

When households cross thresholds in tax schedules their incentives to save, spend, and hold different assets can change substantially. To help identify the structural model described in the next section, I exploit variation in tax policy over time in addition to cross-sectional differences. Changes to estate taxation and residential property transaction taxes provide a source of quasi-experimental variation. This varies the returns to leaving a bequest, to holding different assets, and the cost of transforming housing wealth into liquid wealth. Furthermore, large fluctuations in house prices lead to ‘bracket creep’ when price appreciation pushes households into higher tax brackets. This section summarizes important changes to the tax environment over the sample. Appendix C contains a full list of reforms and discusses anticipation.

I then show how the moving decisions of older households responds to changes in financial incentives. This exploits thresholds in the transaction tax schedule using a regression discontinuity research design. The results highlights the quantitative importance of the financial incentive and housing windfall mechanism. Furthermore, it demonstrates why tax policy variation is a useful source of empirical identification.\(^\text{10}\)

3.1 Inheritance Tax in the Sample Period

Contrary to its name, UK Inheritance Tax is levied on the estate of an individual who dies and not on the recipient of a bequest. When an individual leaves the entirety of their estate to a spouse or civil partner there is no inheritance tax levied.

Inheritance Tax is a constant rate of 40% of the estate above an exemption threshold indexed to RPI. In 2010, this threshold was £325,000. A major reform imple-

\(^{10}\)A recent literature has shed light on the effect of housing transaction taxes and their impact on transaction volumes (Best and Kleven, 2018), sale prices (Besley et al., 2014; Kopczuk and Munroe, 2015; Slemrod et al., 2017) and mobility decisions (Hilber and Lyytíkäinen, 2017). A concern is these findings are driven by younger households who have a higher baseline mobility rate - if this were true there would be no additional identifying power from these reforms when studying older households. How strongly older households respond to changes in financial incentives is an empirical question. My approach draws on Hilber and Lyytíkäinen (2017) who study the moving decisions of working age UK households and find effects on a similar order of magnitude to older households.
mented on October 9th 2007 increased the exemption threshold by any unused proportion of a deceased spouse or civil partner’s nil-rate band. To illustrate, suppose the husband died in 2003 and left £50,000 to other heirs and the wife died in 2010. The exemption threshold for the wife would be £600,000 because she is entitled to the full amount of her own exemption threshold (£325,000) and the unused proportion of her husband’s nil-rate band (£325,000 less the £50,000 already bequeathed).

3.2 Housing Transaction Taxes in the Sample Period

The Stamp Duty Land Tax (SDLT) replaced the pre-existing Stamp Duty in 2003, and is a transaction tax levied on all residential properties in the UK. During the sample period, the tax takes the form of a percentage rate charged on the whole purchase price if the price is above a particular threshold. The SDLT varies the average tax rate creating discontinuous changes, or notches, in the choice set of retirees. There are numerous changes over the sample period. In 2005 the threshold for the lowest rate, charged at 1%, doubled and increased again in 2006. In 2011, new higher rates charged at 5% and 7% for all properties above £1 million and £2 million were introduced. In addition to these changes, in 2008 the UK government introduced the ‘Stamp Duty Holiday’ a temporary (15 month) increase to the lower threshold from £125,000 to £175,000 expiring on December 31st 2009. Table A.1 summarizes the different tax regimes over the duration of my sample.

How do transaction taxes affect retired households? Those with large amounts of wealth tied up in their home face these costs when moving house. Relative to a world with no transaction tax this creates large disincentives. For downsizers, transaction taxes function as an implicit tax on their home equity extraction. For example, downsizing by £100,000 from a £400,000 house yields an effective 10.2% tax rate.11

11Under the SDLT policy the transaction tax levied on the new purchase is £9,000 while £12,000 on the sale gives the 10.2% implicit tax rate on equity withdrawal (40% of £12,000 and 60% of £9,000). For a a household with a house worth £250,000 downsizing to a house worth £200,000, releasing 20% of the equity in their home, the effective tax rate on the equity released is 13.2% (40% of £7,500 and 60% of £6,000 divided by the £50,000 base). A substantial body of evidence suggests effective incidence often falls on sellers irrespective of the statutory incidence. Besley et al. (2014) estimate 40% of the incidence falls on sellers using variation from the UK ‘Stamp Duty Holiday’. I use this estimate in the calculation above. Kopczuk and Munroe (2015) present alternative estimates of transaction tax incidence using New Jersey Mansion taxes and find it is entirely incident on the seller. In contrast, Slemrod et al. (2017) estimate equal incidence using notches in Washington, DC.
3.3 The Impact of Financial Incentives on Moving House

Identifying the effect of housing wealth windfalls in the expenditure and savings decision of retirees is difficult. Cross-sectional comparisons of high and low housing wealth households are biased as those with different portfolios may have different preferences or expectations about the future. Instead, I rely on quasi-experimental variation in the financial returns to moving house generated by the tax code.

I exploit a discontinuous increase in the housing transaction tax burden using a regression discontinuity research design to show there is an economic and statistically significant reduction in home mobility when the financial incentives for moving house decline. This a reduction in the extensive margin of home equity adjustment or portfolio rebalancing in response to an exogenous increase in illiquidity.

I focus on a notch at the £250,000 threshold because it remains constant throughout the sample period. Sale values exceeding this threshold experience an increase in the average tax rate paid on the transaction from 1 to 3%. This is a discontinuous increase in the SDLT burden of £5,000 (Figure 4a). Shocks to aggregate house prices throughout the sample create variation in underlying self assessed house values leading to random assignment across this threshold. The outcome variable of interest, Move_{i,t}, is a dummy variable denoting a household’s mobility between waves t and
\[ Move_{i,t} = \beta_0 + \beta_1 \text{Treat}_{i,t} + f(\text{HouseValue}_{i,t}) + \delta X_{i,t} + u_{i,t} \]  

(1)

The vector of control variables, \( X_{i,t} \), includes a polynomial in household age, a polynomial in PI, household demographics, and wave and region indicators. I present results approximating the flexible function of house value \( f(\cdot) \) in the conditional expectation function using a non-parametric local linear estimator and quadratic polynomial with common slope. Additionally, I drop all households more than 30% below the threshold to avoid contamination from the ‘Stamp Duty Holiday’.

The key identifying assumption is that, conditional on the covariates, \( u_{i,t} \) is uncorrelated with the treatment indicator \( \text{Treat}_{i,t} \). In regression discontinuity frameworks, this is satisfied if other covariates vary smoothly and the forcing variable \( (\text{HouseValue}_{i,t}) \) cannot be manipulated. Two features of the data reduce the concern of manipulation: first, moving house is measured in the following wave so the reported home value is predetermined and, second, self assessed home valuation is not the actual sale price used to calculate the SDLT burden. Manipulation of sale prices and the implied disincentive to sell is part of the estimated effect. Following Kolesár and Rothe (2018) standard errors are clustered at the household level and I provide alternative confidence intervals with guaranteed coverage properties in appendix D.\(^{12}\)

Figure 4b plots the results graphically showing a sharp decrease in mobility for those households who exceed the £250,000 threshold. Table 2 presents results from the regression analysis using both non-parametric and parametric estimators and varying the window around the stamp duty threshold included in the regression.

The first row shows the results for the preferred specification using a local linear estimator. For all windows around the discontinuity the non-parametric method yields similar point estimates. However, for small bands around the cut-off these results are imprecisely estimated where the sample size is small. For larger bands around the discontinuity in the SDLT schedule the results are precisely estimated and the negative effect of an increase in the transaction tax burden is statistically significant. The parametric specification in the second row has a similar pattern and point estimates. The treatment effect of exposure to higher transaction taxes is negative in all specifications and the magnitude of the effect is robust to alternative estimation

\(^{12}\)Appendix D also provides results for different order polynomials and additional robustness tests.
windows and methods for approximating the conditional expectation function.

The estimates of exposure to higher transaction taxes, a 2.85 percentage point reduction in mobility for the optimal bandwidth, show increases in transaction taxes for retirees are both economically and statistically significant. The fraction of retirees moving house falls by 50% in response to a reduction in the financial returns to moving house - highlighting the empirical relevance of a housing windfall mechanism.

4 A Model of Savings After Retirement

The previous sections highlights both extensive and intensive margin adjustments to retirees’ portfolios. To better understand their responses to changing financial incentives over the whole retirement period, this section introduces a model of their savings decisions. The model generates key empirical results in Section 2 and sheds light on how this mechanism interacts with the design of social insurance. It includes a rich model of housing decisions incorporating institutional features from the UK.

Households face idiosyncratic and exogenous risk in health status, mortality, LTC expenditures, and, for couples, the structure of their household. In addition, households are exposed to aggregate risk in the form of a common stochastic process for house prices. Retirees are partially insured by the tax and transfer system including

<table>
<thead>
<tr>
<th>CEF Approximation</th>
<th>Band around cutoff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10%</td>
</tr>
<tr>
<td><strong>Non-parametric</strong></td>
<td></td>
</tr>
<tr>
<td>Local Linear</td>
<td>-0.0278</td>
</tr>
<tr>
<td></td>
<td>(0.0334)</td>
</tr>
<tr>
<td><strong>Parametric</strong></td>
<td></td>
</tr>
<tr>
<td>Quadratic</td>
<td>-0.0365</td>
</tr>
<tr>
<td></td>
<td>(0.0241)</td>
</tr>
<tr>
<td>N</td>
<td>1224</td>
</tr>
</tbody>
</table>

All regressions additionally control for wave fixed effects, a polynomial in age, household demographics, a polynomial in permanent income and region dummies (Equation 1). Following Kolesár and Røthe (2018), Standard Errors are clustered by household and optimal bandwidth selection follows Imbens and Kalyanaraman (2012). The Akike Information Criterion is shown in italics for the parametric specification. * p < 0.10, ** p < 0.05, *** p < 0.01

Table 2: The Effect of Transaction Taxes on Household Mobility
means-tested transfers for LTC expenses.

Retirees begin retirement single or in a couple. For couples, the survivor continues as single if their spouse dies and I assume singles cannot remarry. Family structure and gender affect utility, health transitions, mortality, LTC costs and income.

Each period, a household chooses their expenditure on non-housing consumption, the size of the house they wish to live in, and the stock of financial assets for the next period. Financial assets are perfectly liquid and yield risk free return $r$. There is no borrowing.\footnote{I discuss the empirical support for this assumption in Appendix E.} Housing assets require maintenance to offset depreciation at rate $\delta$ and have a price $p_h$ which households take as given. Renters, with zero housing wealth, rent housing services at a fraction of the sale price $r^h$ or can purchase a house.

At the beginning of each period, households observes their age, PI, who is alive in the household, liquid wealth, housing wealth, health, LTC expense shock and the level of aggregate house prices. Decisions are made after shocks are observed and new shocks arrive at the end of the period after decisions have been made.

To capture a key source of non-stationarity in the policy environment of retirees and to leverage it as an additional source of identifying variation, I allow estate and transaction tax rules to change over time. This creates additional variation in the financial incentives retirees face over time. For simplicity, I describe the model for a single policy regime. When solving and simulating the model during estimation, I assume policy changes are unanticipated\footnote{The exception is “Stamp Duty Holiday” where. In this case, I treat the reversal of the policy as perfectly anticipated in line with the institutional context of the temporary cut.}, solving it under each policy regime.

\subsection{Demographics}

A household is either a single man, single woman, or a couple. The state variable $f$ is the family structure describing their demographics.

$$f \in \{\text{Single Man, Single Woman, Couple}\}$$ 

\footnotetext[13]{I discuss the empirical support for this assumption in Appendix E.}
\footnotetext[14]{The exception is “Stamp Duty Holiday” where. In this case, I treat the reversal of the policy as perfectly anticipated in line with the institutional context of the temporary cut.}
4.2 Preferences

Preferences are time separable, with a constant discount factor $\beta$. Households maximize expected utility and the per-period utility function is given by:

$$ u(f, c, s) = \frac{n_f \left( \frac{1}{\alpha_n} c^\sigma s^{1-\sigma} \right)^{1-\gamma} - 1}{1 - \gamma}, $$

where $c$ is non-housing consumption and $s$ denotes housing services. The number of adults, $n$, is a deterministic function of family status, $f$, with $\alpha_n$ the consumption equivalence scale for total consumption. In this specification, $\gamma$ is the coefficient of relative risk aversion and $\sigma$ is the weight of non-housing consumption relative to housing services. Owner occupied housing yields housing services at the rate $1 + \omega$.\(^{15}\)

I assume bequests are only possible when the final surviving member of the household has died. Bequests, $b$, are the net of tax consolidated value of the estate and utility from bequests, takes the form of a warm glow bequest motive (Andreoni, 1989; De Nardi, 2004). The functional form for $\phi^i(b)$ is given by:

$$ \phi^i(b) = \frac{\phi^i_1 (\phi^i_2 + b)^{(1-\gamma)} - 1}{1 - \gamma}, $$

where $\phi^i_1$ controls the weight on bequests relative to lifetime consumption, while $\phi^i_2$ controls the curvature and the extent to which bequests are a luxury good.\(^{16}\) This simple specification is consistent with altruism (as in Abel and Warshawsky, 1988) or other interpretations of the bequest motive (e.g. the strategic motive in Bernheim et al., 1985, or egoism). Allowing these parameters to vary across households is a parsimonious and tractable way of incorporating heterogeneity in families without taking a stance on the form of the bequest motive or modelling multiple generations. Additionally, durable goods providing consumption flows, such as housing, lower the cost of leaving an inheritance. Consequently, this heterogeneity allows for greater

\(^{15}\) $\omega$ affects the relative price of renting housing services and captures benefits from ageing in place as a homeowner. For retirees, the ability to make modifications to their home may be more valuable as their health and mobility decline. Additionally, many retirees who rent are either in public housing or LTC facilities and may experience lower quality housing. Alternatively, they may directly value the additional commitment benefit offered by homeownership when interacting with their children (Barczyk et al., 2019). I impose a within period Cobb-Douglas aggregator for total consumption as many studies, such as Davis and Ortalo-Magné (2011), find constant housing expenditure shares.

\(^{16}\) For positive $\phi^i_2$ marginal utility of small bequests is bounded, while the marginal utility of large bequests declines more slowly than consumption.
flexibility in both inter- and intra-temporal patterns of substitution at older ages.

4.3 Income, Health, Mortality and LTC Spending

**Income**  Households earn a return $r$ on their financial assets $a$. Non-asset pension income $y$ is deterministic and depends on age $j$, current family structure $f$ (which captures size and gender) and PI $I$:

$$y = y(j, f, I)$$  \hspace{1cm} (5)

In addition to an Estate Tax, $\tau_b$, and Stamp Duty levied on housing transactions, $\tau_h$, income taxes, $\tau_y$, are due on income from pensions and financial assets.

**Health Status**  Health status takes one of three values for living household members

$$m \in \{\text{Good}, \text{Bad}, \text{ADL}, \text{Dead}\},$$  \hspace{1cm} (6)

and transitions according to a flexible age, family structure and PI dependent Markov process. Allowing the process to vary with PI and family composition captures differences in health investment that are not modelled directly. The direct effects of aging, health status, and gender on health production or deterioration are also captured by the Markov process. Following Ameriks et al. (2020) I use difficulties with Activities of Daily Living (ADLs) to define the worst health state. ADL measures capture a range of needs associated with institutional LTC use and community care. For couples, $m$ denotes a pair with a health status for each member - for notational convenience I continue to use $m$ to denote the nine valued health status for the couple.

**Mortality**  Individuals face exogenous mortality risk depending on age, family structure, health status and PI. $\eta(j, I, m, f)$ denotes household survival probabilities.

**LTC Spending**  For US retirees, out-of-pocket medical expenditure risk is an important driver of precautionary savings. In the UK, comprehensive coverage for acute and chronic medical expenses is free at the point of use. However, LTC risks pose considerable out-of-pocket risk with lifetime costs exceeding £100,000 for 10% of individuals (Dilnot et al., 2011). The National Health Service (NHS) provides coverage
for acute and chronic expenses for the entire UK population.

I define $m_{x,j}$ as the flow of all LTC expenses incurred between $j$ and $j-1$. Consistent with evidence of limited income elasticity for LTC needs (e.g. Ameriks et al., 2020), they are exogenous and depend on current and previous period health status and family structure, PI, age, and a standard normal idiosyncratic shock, $\epsilon_{m_{x,j}}$:

\[
\ln m_{x,j}(\cdot) = \mu_{m_{x,j}}(m_{j-1}, m_j, I, f_{j-1}, f_j, j) + \sigma_{m_{x,j}}(m_{j-1}, m_j, I, f_{j-1}, f_j, j) \times \epsilon_{m_{x,j}} \tag{7}
\]

The government acts as a payer of last resort for LTC expenses when individuals have insufficient resources or when resources are exhausted paying LTC expenses. This imposes a 100% marginal tax rate on private resources by requiring retirees first spend down their wealth. Following Hubbard et al. (1994, 1995), I model this means-tested benefit as a health state dependent consumption floor, $c_{\min}$. Couples are subject to different means-testing rules that cap their spending at 50% of their joint financial assets when only one spouse has LTC needs. In other words, 100% of their house and 50% of their remaining wealth are not subject to the spend down requirement. I allow the floor to depend on family structure capturing additional insurance and incentives to hold wealth in housing for couples.

### 4.4 Housing Market and House Prices

Moving house is costly. I model two types of cost: the statutory transaction tax and additional financial costs. The total value of a house, $h$, is $p_h h$ and if a household adjusts their housing stock they must pay the following adjustment cost:

\[
Q(h_{t+1}, h_t, p_{h,t}) = \mathbb{I}[h_{t+1} \neq h_t] \times \left( p_{h,t} h_{t+1} - p_{h,t} h_t (1 - \pi) + F + (1 - \kappa) \cdot \tau_h(p_{h,t} h_{t+1}) + \kappa \cdot \tau_h(p_{h,t} h_t) \right) \tag{8}
\]

The total cost consists of three parts. First, the change in housing evaluated at today’s price net of a proportional cost $\pi$. The proportional component of the transaction cost allows the costs to vary between houses of different values or sizes.\(^{17}\) Second, a fixed cost, $F$, capturing the invariant component. Third, the transaction tax, $\tau_h(\cdot)$, with incidence on the seller $\kappa \in [0,1]$. Allowing for the effective incidence to differ

\[^{17}\text{The financial value of hassle costs vary with size because larger houses require moving, or disposing of, more possessions or take longer to sell in thinner markets. Real costs may be proportional because the intricacy of legal agreements or surveying varies with the property value or size.}\]
from the statutory incidence incorporates incentives to manipulate sale prices without modelling the bargaining protocol or other features of the real estate market.

Homeowners must pay a proportional maintenance cost, $\delta$, each period. Current renters, who may choose to purchase, rent housing services at a fraction $r^h$ of the sale price. Consequently, rental prices include housing market volatility.

House prices are stochastic and their log evolves as a standard AR(1) process:

$$\ln(p_{h,t+1}) = \mu_h + \rho_h \ln(p_{h,t}) + \epsilon_{h,t+1}, \quad \epsilon_{h,t+1} \sim N(0, \sigma^2_h) \quad (9)$$

Drift $\mu_h$ reflects trend growth in house prices. This formulation is common and fits the data at both individual and aggregate levels well (see Nagaraja et al., 2011; Berger et al., 2018, respectively). I model aggregate house price movements, thus, the price level is common to all households in time period $t$.

### 4.5 Recursive Formulation and Household Problem

I describe the recursive formulation for a current homeowner (renters differ only in terms of rental expenditures). Letting $a_t$ denote the liquid wealth of retirees in time period $t$ and $r$ denote their return, total post tax income is $\tau_y(r a_t + y_t(\cdot), \tau, f_t)$ with vector $\tau$ summarizing the tax system. To economize on state variables, I follow Deaton (1991) and redefine the problem in terms of cash-on-hand

$$x_t = a_t - c_t - Q(h_{t+1}, h_t, p_{h,t}) - \delta h_{t+1} - m x_{t+1} + \epsilon_{h,t+1}, \quad \epsilon_{h,t+1} \sim N(0, \sigma^2_h) \quad (10)$$

which has the following law of motion

$$x_{t+1} = x_t - c_t - Q(h_{t+1}, h_t, p_{h,t}) - \delta h_{t+1} - m x_{t+1} + \epsilon_{h,t+1}, \quad \epsilon_{h,t+1} \sim N(0, \sigma^2_h) \quad (11)$$

where savings, which are constrained to be non-negative, are given by

$$a_{t+1} = x_t - c_t - Q(h_{t+1}, h_t, p_{h,t}) \geq 0, \quad \forall t \quad (12)$$

Cash-on-hand is net of housing maintenance costs and LTC expenses, but includes income after taxes and transfers. The tax function accounts for means-tested transfers excluding those covering LTC expenses. Means-tested transfers, $tr_t(\cdot)$, bridge the gap between a minimum consumption floor and a household’s resources and provide a
ceiling for couples’ LTC expenses. Define the resources available next period after tax, but before government transfers with

\[ \bar{x}_{t+1} = a_{t+1} - \delta h_{t+1} - mx_{t+1} + \tau g(r a_{t+1} + y_{t+1}, \tau, f_t). \]  

(13)

Consistent with assistance for LTC expenses which depends on total resources, housing, health, and family structure, government transfers are defined as

\[ tr_t(\bar{x}_t, f_t, h_t, m_t, p_{h,t}) = \max \{ 0, c_{min}(f_t, h_t, m_t) - (\bar{x}_t - x_{D,t} - h_{D,t}) \} \]  

(14)

where \( x_{D,t} \) and \( h_{D,t} \) are exemptions (or disregards) on combined liquid assets and income and housing assets respectively.\(^{18}\) The law of motion for cash-on-hand next period can thus be rewritten as

\[ x_{t+1} = \bar{x}_{t+1} + tr_{t+1}(\bar{x}_{t+1}, f_{t+1}, h_{t+1}, m_{t+1}, p_{h,t+1}). \]  

(17)

Finally, bequests are exposed to LTC costs and constrained to be non-negative, thus, the after tax value of their consolidated wealth is given by:

\[ b_t = \tau_b(\max \{ Q(0, h_{t+1}, p_{h,t}) + a_{t+1} - mx_{t+1}, 0 \}). \]  

(18)

The recursive formulation depends on \( i \) due to idiosyncratic preferences for bequests. The state variables of a household are given by \( \Omega = \{ j, f, I, m, h, x, p_h \} \) with next period values denoted by a prime. These variables are: age \( (j) \), family structure \( (f) \), PI \( (I) \), health status \( (m) \), housing stock \( (h) \), cash-on-hand \( (x) \), and the aggregate

\[ x_{D,t} = X_D(f_t, \bar{x}_t, m_t) = 1[m_1 \neq ADL \cap m_2 \neq ADL \cap f_t = couple] \times \bar{x}_t / 2 \]  

(15)

\[ h_{D,t} = H_D(f_t, h_{t}, p_{h,t}, m_t) = 1[m_1 = ADL \cap m_2 = ADL \cap f_t = couple] \times h_{t}p_{h,t} \]  

(16)

\(^{18}\)Households who cannot afford the minimum level of consumption after liquidating their assets must sell their house and spend all wealth. They begin next period as renters and receive transfers to meet the consumption floor. Disregards are functions of state variables following the rules summarized in Section 4.3, let \( m_1^i \) and \( m_2^i \) denote health for arbitrary individuals within the household:
house price level \((p_h)\). The recursive problem for homeowner \(i\) is:

\[
V^i_j(\Omega) = \max_{(c, h', a')} \left\{ u(f, c, s) + \beta \cdot \eta(j, I, m, f) E[V^i_{j+1}(\Omega') \mid \Omega, h', a'] \right. \\
+ \beta (1 - \eta(j, I, m, f)) E[\phi^i(b) \mid \Omega, h', a'] \}
\]

subject to equations (2)-(9) and (12)-(17) and bequests are constrained by (18). Households choose non-housing consumption, \(c\), savings in financial assets (before LTC costs), \(a'\), and the new housing stock, \(h'\). They form expectations over individual mortality, family structure tomorrow, \(f'\), household health, \(m'\), the transitory component of LTC expenses, \(\epsilon_{mx}\), and the level of house prices, \(p_h'\). LTC expense risk implies households form expectations over realized cash-on-hand tomorrow, \(x'\), and the possibility they are compelled to sell their house to finance LTC costs.

## 5 Estimation

I adopt a two-stage estimation strategy. In the first stage I estimate (or calibrate using existing evidence) parameters that can be cleanly identified outside of the model. I fix the consumption floor and household equivalence scales based on pre-existing evidence. Additionally, I discretize latent preference heterogeneity into \(K\) groups using a k-means algorithm to reduce dimensionality (Bonhomme et al., 2021).

In the second stage I estimate the remaining model parameters, the discount factor, risk aversion, weight on housing, homeownership premium, transaction costs and heterogeneous bequest parameters,

\[
\theta = (\beta, \gamma, \sigma, F, \pi, \{\phi^1_k, \phi^2_k\}_{k=1}^K),
\]

using the method of simulated moments (MSM) and taking the first stage parameters and groups as given. The value of these parameters minimises the weighted distance between simulated moment conditions and the data using a GMM criterion function

\[
\hat{\theta} \arg \min_{\theta \in \Theta} G(\theta)'WG(\theta),
\]

with \(W\) the inverse-diagonal weighting matrix. The target moment conditions are:

1. For initial homeowners, I match mean liquid and housing wealth by age, PI,
and cohort. For renters, I match mean liquid wealth by age and cohort.

2. I match mean subjective bequest probabilities by age, PI, and cohort for initial homeowners and by age and cohort for initial renters. I use the self-reported probability of leaving a bequest greater than £150,000.

3. Moving is costly, but liberates liquidity from housing. Thus, I match the fraction of initial homeowners moving house and homeownership rates by age and cohort.

The MSM approach is standard. Appendix G provides a detailed description. Due to the frequency of tax reforms, I do not explicitly target pre and post periods or the level and treatment effect using indirect inference. Instead, target moments embed behavioural responses to longitudinal variation in tax policy. In addition, I use estimates of the effect of transaction taxes from the regression discontinuity design to validate the model so do not target this explicitly in estimation.

5.1 Identification

Separately identifying precautionary and bequest motives is a long standing challenge (De Nardi et al., 2016b; Lockwood, 2018). I combine data on wealth composition and subjective bequest probabilities with exogenous policy reforms (discussed in detail in Section 3), and variation in house prices over time.

Policy reforms shift the returns and risks associated with holding different assets and moving house. Along with house price changes, this creates longitudinal variation in incentives which provides an additional source of identification as it requires the model to match changes in behaviour when incentives change. Additionally, how decisions vary with age and across the PI distribution uses differences in health, mortality and LTC expense risks to identify the model.\footnote{Even when panel data is available, many MSM approaches match repeated cross sections or pool time periods. Instead, this paper’s approach accounts for, and exploits, multiple sources of non-stationarity over time. This uses cross cohort comparisons where the fully specified model controls for differences across households in a given calendar year. I assume preference parameters in the structural model are unaffected by policy or house price changes - an exclusion restriction. How these comparisons vary with age and PI provides additional identifying variation due to differences in income, expected longevity and future LTC expenses. Those with low PI face lower longevity (Table 3) and higher LTC costs while alive. In contrast, those with higher PI survive for longer and experience lower LTC costs. These differences help pin down the demand for self-insurance.}

In complex non-linear models, all moments potentially influence all parameters, however, I provide intuition for why particular moments are more informative about certain parts of the model.
Parameters in the period utility function  Households vary in their ability to self-insure LTC costs by their level of wealth and the risks they face vary with age and PI. Their liquid wealth determines their ability to self-insure in the short run. Matching liquid wealth identifies risk aversion $\gamma$. The total level of wealth captures their ability to self-insure over longer horizons and the extent of life cycle saving identifying $\beta$ the intertemporal discount factor.

Renters’ savings and expenditure strongly respond to the consumption share of housing, $\sigma$, because it determines their expenditure share on rent. House prices changes create variation in renters’ spending, saving and demand for liquid buffers identifying $\sigma$. In contrast, I identify the benefits of homeownership, $\omega$, by matching the behaviour of initial owners: the fraction remaining homeowners by age and cohort.

The Cost of Moving  Retirees move house when the benefits exceed the costs. Variation in the size of transaction taxes lead to differences in these costs. Household responses to these changes is informative about the size of the estimated costs of moving, $\pi$ and $F$, relative to the observed tax costs.

Bequest Motives  The reform to estate taxation shifts the return to saving for a bequest without changing the utility of future lifetime consumption. The extent to which households adjust their savings decisions in response to this tax reform helps identify the bequest utility parameters. As bequests are slow to adjust and only realised at death, I match information on expected future bequests. This survey measure provides information on the savings of each household under both estate tax regimes - allowing the econometrician to fully exploit the reform without the infeasible requirement that the same household’s bequest is observed under both tax regimes. Information on each household’s future bequests allows me to identify the average strength of bequest motives, but also heterogeneity in the population.

5.2 Econometric Concerns

Non-stationarity introduced by cohort and time effects could lead to biased estimates of model parameters. Wealth holdings at the same age may differ due to differences in income growth, asset prices, asset growth or public policy over the life cycle. Cross sectional moments may attribute differences between cohorts to differences in savings rates by age resulting in biased parameter estimates.
By sampling household initial conditions, controlling flexibly for household PI, and simulating the sequence of observed aggregate shocks and policy reforms faced in their retirement I replicate differences across cohorts and time periods. I construct moment conditions by cohort and calendar year to eliminate this source of potential bias. Formally, this paper makes two important assumptions: first, cohort effects are summarized by their composition and initial characteristics and, second, relevant time effects are captured by policy reforms and changing house prices. This is a structural approach to the age-time-cohort problem which explicitly accounts for differences across households and leverages policy reforms for identification.

Individual mortality is negatively correlated with lifetime income, thus surviving members of a cohort are wealthier on average. To address “mortality bias” (and sample attrition) in the simulations each household is given an observed sequence of mortality, health, and attrition shocks. This is the observed sequence for the data household who provide their initial conditions; therefore any sample selection in the unbalanced ELSA panel is exactly replicated in the simulated panel.

6 Estimation Results

Section 2 reports some of the key facts about housing and liquid wealth I require the estimated model to match. In this section I report a subset of the most relevant features of the first stage model estimates, and discuss second stage estimates.

6.1 First Stage Estimates

The risks and financial incentives facing retirees are key drivers of their saving behaviour and the benefits of different assets, I report the most important results from first stage estimates here and provide complete details in Appendix H.

Mortality and Health Transitions I estimate survival and health status transition probabilities in ELSA using a multinomial logit approach allowing transitions to depend on age, family size, health status and PI. I define the ADL state as individuals with two or more limitations and describe ELSA’s measures in Appendix H. Table

\footnote{Fagereng et al. (2019) argue asset price growth can substantially overstate active saving rates.}
Table 3: Life Expectancy & Expected Duration of ADL difficulties

<table>
<thead>
<tr>
<th>PI Percentile</th>
<th>Men in Good Health</th>
<th>Men in Bad Health</th>
<th>Women in Good Health</th>
<th>Women in Bad Health</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Life Expectancy</td>
<td>ADL Years</td>
<td>Life Expectancy</td>
<td>ADL Years</td>
</tr>
<tr>
<td>Singles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10\textsuperscript{th}</td>
<td>13.65</td>
<td>2.02</td>
<td>11.23</td>
<td>2.85</td>
</tr>
<tr>
<td>50\textsuperscript{th}</td>
<td>16.91</td>
<td>2.32</td>
<td>14.91</td>
<td>2.92</td>
</tr>
<tr>
<td>90\textsuperscript{th}</td>
<td>19.57</td>
<td>1.58</td>
<td>17.83</td>
<td>1.87</td>
</tr>
<tr>
<td>Couples</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10\textsuperscript{th}</td>
<td>13.31</td>
<td>2.15</td>
<td>10.95</td>
<td>3.02</td>
</tr>
<tr>
<td>50\textsuperscript{th}</td>
<td>16.79</td>
<td>2.36</td>
<td>15.10</td>
<td>3.21</td>
</tr>
<tr>
<td>90\textsuperscript{th}</td>
<td>19.29</td>
<td>1.57</td>
<td>17.40</td>
<td>2.19</td>
</tr>
</tbody>
</table>

Conditional on surviving to age 66. ADL years defined by spell with 2 or more difficulties. For couples the calculation assumes both spouses have the same health at age 66.

3 summarizes simulated health and mortality trajectories using these estimates, revealing an important PI gradient to life expectancy for both men and women. Men at the 90th percentile of the PI distribution live 6 years longer than those at the 10th percentile. For women, the difference is halved. Those with lower PI ranks spend longer living with ADL limitations when alive and women both live longer and spend a greater proportion of retirement with ADL limitations irrespective of initial health.

**Long Term Care Costs**  Micro-data on the LTC expenses of UK retirees is scarce. However, Banks et al. (2019) document costs reported by US households in the HRS line up closely with available measures in ELSA. Motivated by this, I estimate the LTC expense process described in equation (7) using the HRS. Effectively this imputes LTC costs across countries. To capture NHS coverage of other medical expenses, health costs are 0 unless a household member has ADL needs.

**Consumption Floor**  The consumption floor, which replicates the effective value of receiving public assistance including any stigma or disutility from receiving state care rather than a statutory value, is taken from Ameriks et al. (2011). For couples this value is equivalized. I calibrate this parameter using US evidence because there is limited information on who pays for LTC expenses or the deaccumulation of wealth by those entering nursing homes in the ELSA data.
Table 4 reports the distribution over types\textsuperscript{21} and group means for elements of $z_i$. Type I are low wealth and PI initial renters who are systematically less likely to leave a bequest. Type IV are the highest wealth and PI homeowners. Types II and III divide remaining homeowners into ‘spenders’ with higher PI, but lower wealth and

\begin{table}[h]
\centering
\begin{tabular}{lllllll}
\hline
Group & Homeowner & Wealth & PI & Bequest Index & N & Share \\
\hline
Type I & 5.5\% & 24,200 & 29.4 & -17.6 & 1,296 & 24.59\% \\
Type II & 98.0\% & 184,600 & 47.1 & -25.21 & 1,487 & 28.22\% \\
Type III & 98.5\% & 323,400 & 34.6 & 35.0 & 1,169 & 22.18\% \\
Type IV & 98.6\% & 640,500 & 83.7 & 10.9 & 1,318 & 25.01\% \\
\hline
\end{tabular}
\caption{Distribution of Latent Household Types}
\end{table}

\textbf{Latent Types} \quad Equation 4 specifies idiosyncratic preference heterogeneity parametrically. I approximate latent heterogeneity with $K = 4$ groups, then estimate group specific parameters treating bequest preferences as non-linear group fixed effects.

Classification flexibly partitions households into $K$ groups, $\mathcal{K} = \{k(i)\}_{i=1}^n$, as an unrestricted function of household level observations, $z_i$, to minimise within cluster sum of squared errors. The vector $z_i$ uniquely recovers the underlying latent heterogeneity as panel length grows: the \textit{injectivity} assumption (Bonhomme et al., 2021).

I select $z_i$ motivated by existing empirical evidence and economic theory and use: initial homeownership status, initial wealth, PI and a bequest preference index constructed from beliefs over future bequests. The first three elements parsimoniously capture life cycle savings and income incorporating correlation between preferences and initial conditions. These are exogenous, but are the outcomes of working life choices. Houses lower the opportunity cost of bequests consumption because they provide a consumption flow. Retirement wealth is determined by early life choices (Venti and Wise, 1998) and stronger bequest motives lead to more wealth accumulation. Combining retirement wealth with PI exploits heterogeneity in lifetime saving rates, distinguishing lifetime spenders (high income, low retirement wealth) from savers (vice versa). Finally, the bequest preference index is a measure of systematic differences in future bequests unexplained by current state variables. I construct a household fixed effect by regressing subjective bequest probabilities on flexible controls for observable state variables. Full details are provided in Appendix H.

\textsuperscript{21}While any labelling is ad hoc, I order types by the average value of initial wealth.
Table 5: Estimated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta )</td>
<td>Annual Discount Factor</td>
<td>0.957</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.00326)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \gamma )</td>
<td>CRRA</td>
<td>3.98</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0291)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \sigma )</td>
<td>Consumption Weight</td>
<td>0.567</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.00298)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \omega )</td>
<td>Ownership Premium</td>
<td>1.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0379)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( F )</td>
<td>Fixed Transaction Cost</td>
<td>13,288</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(96.2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \pi )</td>
<td>Proportional Transaction Cost</td>
<td></td>
<td>14.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.313%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \phi_0 )</td>
<td>Bequest Weight</td>
<td>69.2</td>
<td>5.34\times 10^{-4}</td>
<td>97.9</td>
<td>21.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(96.45)</td>
<td>(2.276\times 10^{-3})</td>
<td>(4.89)</td>
<td>(3.05)</td>
</tr>
<tr>
<td>( \phi_1 )</td>
<td>Bequest Shifter (1,000s)</td>
<td>602.9</td>
<td>66.6</td>
<td>70.2</td>
<td>46.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1587.583)</td>
<td>(29.9)</td>
<td>(6.49)</td>
<td>(26.4)</td>
</tr>
</tbody>
</table>

Standard Errors correct for simulation error and are calculated using the asymptotic variance of the GMM estimator (see Appendix G for details). I report annual values where appropriate.

Table 5: Estimated Parameters

low probability of leaving a bequest and ‘savers’ who are their opposites.

### 6.2 Second Stage Estimates

Table 5 reports the second stage estimates beginning with parameters common across households. The discount factor, \( \beta \), and the coefficient of relative risk aversion, \( \gamma \), are in line with typical life cycle estimates. Together with the estimated weight on non-housing consumption, \( \sigma \), an intertemporal elasticity of substitution for consumption is 0.37 which is standard (see Havránek, 2015, for a meta-analysis).

Taken together, estimated transaction costs imply housing assets have substantial adjustment costs. These are larger than values estimated for younger households. Cocco (2005) argues financial costs often reach 8-10\% of the seller’s home value excluding the effect of disruption. For older households, disruptions are likely to be large as even geographically small moves can isolate them from their community and support network. Furthermore, these estimates include the cost of delay (or ‘fire
Figure 5: Bequest Allocation


sale’) as health deteriorates and immediate care needs rise. The utility premium of homeownership shows retirees value the benefits of aging in place. Rental options are typically either (lower quality) social housing or assisted living facilities restricting the independence of retirees or their ability to modify their home. This estimate is smaller than similar models (e.g. Nakajima and Telyukova, 2020) as the ability to downsize on the intensive margin makes homeownership more attractive.

Estimates for the weight and curvature of the bequest function are difficult to interpret. To aid comparison, Figure 5 reports the share of resources a single retiree facing certain death at the end of the period allocates to bequests.\textsuperscript{22}

The left panel shows bequest allocations for each of the estimated types. There is a large amount of heterogeneity in the strength of the estimated bequest motives with Types I and II having effectively no bequest motives (Kopczuk and Lupton, 2007, find a similar binary distinction). Extrapolating Type I estimates imply motives operative at higher levels of wealth, however, behaviour at this level is not identified as it lies outside the range of observed wealth holdings for Type I. Turning to those with positive bequest motives, estimates for Types III and IV imply similar allocations among those making positive bequests. Estimates for those with positive motives lie within the range of estimates in the literature shown in the right panel. They are stronger than Nakajima and Telyukova (2020), who model a homeownership decision, and

\textsuperscript{22}Full details of this calculation for all studies are given in appendix I
Ameriks et al. (2020) who model the financial wealth of a wealthier population and match strategic survey responses, but weaker than estimates assuming all wealth is liquid. This suggests modeling illiquidity and the demand for housing is key. Furthermore, estimated parameters correlate with lifetime spenders and savers, suggesting a simple model of luxury bequests may be consistent with behaviour after retirement, but not necessarily with accumulation before.

6.3 Model Fit

I require the model to match observed heterogeneity in portfolios, expected bequests, and housing choices by age, cohort, and PI levels. Specifically I target average housing wealth, liquid wealth and the probability of leaving an inheritance conditional on PI group, by cohort and age, for initial owners and these moments unconditional on PI for initial renters. I also target average homeownership and mobility rates for initial owners by age and cohort. These moments identify retirees’ demand for housing, precautionary savings, and heterogeneity in bequest motives. I present a subset of the targets here, for birth cohorts shown in Section 2, with the rest in Appendix J.

Figure 6 highlights important features of retiree portfolios over the sample. The left panel shows housing wealth sharply increases and gradually declines throughout the sample for all cohorts. While there is large variation in the level of housing assets by PI, this trend is common to all PI groups. In contrast, the liquid wealth of initial
 owners declines with age and lower PI retirees dissave more slowly from their liquid wealth. The estimated model matches all of these aspects of the data.

### 6.4 Validation against Quasi-Experimental Evidence

I use moments of the data not targeted in estimation to test the model’s goodness of fit - a notch in the transaction tax schedule and its effect on moving house estimated using a regression discontinuity design in Section 3. This a strict test of the model’s validity as it is required to generate local responses to variation in tax incentives as well as global responses from longitudinal variation in tax incentives embedded in target moments. Importantly, this requires the magnitude of a key mechanism in the model matches the data: how households respond to changes in the financial incentive to transform housing wealth into liquid assets. This is important for predicting behaviour in counterfactual exercises and showing the model reproduces quasi-experimental evidence improves the credibility of these exercises. I estimate an identical equation in simulated data and the ELSA data reported in Table 6.

For all bandwiths, point estimates in the simulated data are a similar order of magnitude and lie within one standard error of the ELSA point estimates. Model estimates are slightly smaller than their data counterparts, but point estimates in the simulated data are economically and statistically comparable to the responses in the data. This suggests the model is able to reproduce both population level responses to tax variation (embedded in the moments) while also producing local responses to variation. This lends considerable support for the magnitude of the liquidity demand and housing windfall channels in the following counterfactual exercises.
Table 7: Household Responses to Unanticipated Shocks

7 Responses to Unanticipated Shocks

To understand the joint role of portfolios and retirement windfalls, I use the estimated model as a laboratory simulating consumption and saving responses to ceteris paribus increases in housing wealth or cash-on-hand, a proxy for lump sum pension payouts.

I simulate changes for a single cohort, those born between 1925 and 1929, take the joint distribution of their initial state variable as given, and assign each member of the cohort the age of 68 (the average age in the first wave of ELSA rounded to be consistent with the length of model periods). Housing wealth windfalls occur at age 70 due to an increase in the level of house prices by 5%. After age 70 the future house prices continue to follow the AR(1) process described in Equation 9 and thus the effect of the unanticipated shock is persistent, but not necessarily permanent. The cash-on-hand windfall is parameterized as an one-time tax rebate (See e.g. Parker et al., 2013; Kaplan and Violante, 2014; Misra and Surico, 2014) at age 70 delivering the same 5% increase in after tax income. Neither windfall is anticipated.

To understand how households respond to changes in their portfolio and total wealth, I report two measures in Table 7: the aggregate Marginal Propensity to Consume (MPC) for annual non-housing consumption and the aggregate Marginal Propensity to Bequeath (MPB). The MPC is measured when the shock arrives and captures contemporaneous non-housing consumption responses. The MPB is measured at death, summarizing how wealth is used over the remaining life cycle.

Table 7: Household Responses to Unanticipated Shocks

<table>
<thead>
<tr>
<th>Shock</th>
<th>Marginal Propensity to Consume</th>
<th>Marginal Propensity to Bequeath</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income</td>
<td>0.12</td>
<td>0.38</td>
</tr>
<tr>
<td>House Price</td>
<td>0.033</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Simulated responses for a single birth cohort to a one-time 5% increase in income and a one-time 5% increase in house prices. Annual MPC is measured at age 70 when shocks arrive and reported.
Panel (a): the Average MPB along the distribution of illiquid wealth. Solid line is the response to a house price windfall and dashed line is the response to a pension windfall (tax rebate) both received at age 70. See Table 7. Panel (b): The distribution of households’ illiquid wealth shares at age 70.

out of a transitory income shock is larger than the housing wealth shock and both estimates are within the range of estimates in the respective literatures.\textsuperscript{24} They imply that for an additional £1 of wealth at age 70, a household consumes an additional 15 pence when they experience an income shock and 3 pence when they experience an increase in house prices. Retirees use housing wealth windfalls to finance retirement spending, but the consumption increase is smaller than from pension windfalls.

In both experiments, a large, economically significant fraction of one generation’s good luck is shared with the next. 1/4 of the house price shock’s PDV is transmitted to bequests. However, the transmission of the income shock is over 1.5 times larger.\textsuperscript{25}

Households respond differently to the two shocks over time - especially those who are liquidity constrained or likely to be during their remaining lifetime. In response to an income shock, low wealth households with larger housing portfolio shares are less likely to downsize. Marginal downsizers in the baseline have more cash available to spend today and find downsizing less attractive. These households no longer liquidate housing wealth, no longer pay adjustment costs and retain additional housing returns because the income shock alleviates liquidity constraints in some states of the world. This effectively increases their lifetime saving.

\textsuperscript{24}For example, Aladangady (2017) finds an MPC out of housing wealth of 0.047 on the dollar.\textsuperscript{25} The order of magnitude is consistent with the estimated MPB out of social security income in Lee and Tan (2019), but substantially larger than the MPB in Altonji and Villanueva (2007).
Simulated responses for a single birth cohort to a one-time 5% increase in income and a one-time 5% increase in house prices. Annual MPC is measured at age 70 when shocks arrive and reported. To isolate the effect of preferences, the correlation with initial conditions is set to 0.

Table 8: Household Responses to Unanticipated Shocks by Latent Type

In contrast, an unanticipated increase in the value of housing wealth actually reduces the savings of these same households over their remaining lifespan. Marginal households increase the frequency with which they move house to access otherwise trapped home equity because the financial return to downsizing has grown. Households increase their cash-on-hand by similar amounts to the liquid wealth windfall, but this is now driven by changes in the intensive and extensive margins of downsizing. Thus, retirees who face liquidity constraints, either today or in some future states of the world, behave differently when they experience the two windfalls. When house prices increase, they use this additional wealth to relax liquidity constraints, but do so by economizing on housing consumption and bequests. They pay large adjustment costs in the process. Constrained households and how they trade off housing for liquidity is the key driver of differences in the MPB.\textsuperscript{26} Figure 7 displays this heterogeneity along the distribution of the illiquid wealth share, the ratio of illiquid wealth to total resources. In line with standard intuition, those with high liquidity have larger MPBs out of housing wealth. However, the population of households at the margin of lifetime adjustment drives the aggregate reversal.

While liquidity constraints are important, there is considerable heterogeneity across retirees. Table 8 highlights another key dimension: Types I and II who have weaker bequest motives have larger consumption responses to pension windfalls and smaller MPBs.\textsuperscript{27} In contrast, there are smaller differences in the response to house price shocks. Declining health has a similar effect, increasing MPCs and lowering

\textsuperscript{26}House prices are \textit{persistent} not \textit{permanent}: the mechanical effect of the house price shock at age 70 declines. Even if they do not adjust their behaviour after a house price shock, its transmission to bequests will be smaller. However, estimated parameters imply this effect is negligible

\textsuperscript{27}To isolate the effect of preferences from heterogeneity in initial conditions Table 8 additionally eliminates the correlation between preferences and initial conditions

<table>
<thead>
<tr>
<th>Shock</th>
<th>MPC by Type</th>
<th>MPB by Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Income</td>
<td>0.16</td>
<td>0.16</td>
</tr>
<tr>
<td>House Price</td>
<td>0.031</td>
<td>0.031</td>
</tr>
</tbody>
</table>
MPBs, as households face lower survival probabilities and an increase in the probability of catastrophic LTC expenses - reducing effective planning horizons.

8 Differential Means-Testing of LTC Benefits

Means-tested benefits for households who have large LTC expenditures, but limited private resources are common (OECD, 2011). In the UK, means-testing is applied at the individual level and a single retiree must spend down their private assets (housing and liquid wealth) before qualifying for public assistance.

Applying individual means-testing to couples requires allocating joint resources to each spouse. The UK government assigns 50% of the joint financial wealth to the spouse with LTC needs and 50% to their partner. In contrast, they assign 100% of the house to the healthy partner. Consequently, couples no longer face an implicit spend down tax rate of 100%. This insures spouses against their partner’s risks, but creates asymmetries in social insurance’s generosity for couples and singles.

I simulate changes to the generosity and design of this means-testing, to quantify the value of this additional insurance. I first eliminate both exemptions \((h_{D,t} = x_{D,t} = 0)\) that apply to couples with LTC expenditures and, second, eliminate the financial asset exemption \((x_{D,t} = 0)\). I compare the resulting changes in government spending to the changes in retiree welfare. To measure the costs associated with these reforms I compute the present discounted value (PDV) of changes to the government budget constraint including implicit changes covered by disregarded assets and differences in taxes paid. Welfare changes are measured by compensating variation (CV) defined as an immediate cash-on-hand payment leaving retirees indifferent to the reform.

This approach makes three assumption. First, I assume it costs the government £1 to provide £1 of payments and compare the compensating variation with the actuarial value of the alternative policy. Second, reforms are not revenue neutral. The cost of providing both exemptions exceeds the cost of providing only one. For comparison, I compute the value per £1 of government spending as the ratio of costs to compensating variation. A ratio above 1 implies that eliminating the program and

\[28\text{In Medicaid, a US program with many similarities, houses are deemed countable assets while homes are excluded. A house qualifies as a home if a community spouse or dependent relative resides there or a nursing home stay is deemed temporary with intent to return. In practice, the homestead exemption applies to many singles - a third of single medicaid recipients own homes (Achou, 2020).}

\[29\text{This rules out other methods to make transfers more or less attractive to potential claimants.}\]
<table>
<thead>
<tr>
<th></th>
<th>Δ PDV of payments</th>
<th>Compensating Variation</th>
<th>Ratio: -CV/ΔPDV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Transfers Disregard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Initial Owners</td>
<td>-9131 33 -5533</td>
<td>59599</td>
<td>6.53</td>
</tr>
<tr>
<td>Top PI quartile</td>
<td>-9632 -75 -3948</td>
<td>62261</td>
<td>6.46</td>
</tr>
<tr>
<td>2nd PI quartile</td>
<td>-9081 69 -5936</td>
<td>61006</td>
<td>6.72</td>
</tr>
<tr>
<td>Bottom 50% PI</td>
<td>-8688 104 -6674</td>
<td>55464</td>
<td>6.38</td>
</tr>
</tbody>
</table>

Note: Columns (1)-(3): £increase in the PDV of government costs as of age 68. Column (4): £transfer needed to compensate retirees for the reform. Column (5): Ratio column 4/column 1

Table 9: The Costs and Benefits of Eliminating All Exemptions for Couples

lump sum redistributing proceeds to retirees would be welfare decreasing. Third, I assume reforms are unanticipated, ruling out changes to portfolio composition, saving or marriage markets over the working life and measures the effect of a reform on current retirees. I simulate changes for the same cohort as in Section 7 selecting a subsample who are in couples and who own their own home at 68.

Specifically, compensating variation is computed at age 68 (the initial age in simulation) and defined as $\chi_{68} = \chi_{68}^i(f_{68}, I, m_{68}, h_{68}, x_{68}, p_h)$ solving

$$V_{68}^i(f_{68}, I, m_{68}, h_{68}, x_{68}, p_h) = V_{68}^i(f_{68}, I, m_{68}, h_{68}, x_{68}, p_h | Reform),$$

with $V_{68}^i(\cdot)$ the age 68 value function computed for a given set of state variables. This forward looking ex-ante measure incorporates both mechanical effects and the behavioural responses to the reform and I report results for group averages.

Table 9 presents results from eliminating both exemptions for couples. The PDV of total payments is reported in the first column. Columns 2 and 3 separate this into direct transfers and implicit payments through disregarded assets.\(^3^0\) Column 1 shows that on average there is a large reduction in the cost born by the government. Pooling together all married homeowners in the first row, the average reduction is over £9,000. While the reduction in payments comes from a decrease in disregards, this is partly offset by an increase in transfers because retirees now deplete their private resources and qualify for direct transfers (columns 2 and 3). Splitting results for initial owners along the PI dimension reveals modest heterogeneity in the size of the implicit transfer from exempting assets, however, the likelihood of receiving direct

\(^{30}\)Columns 2 and 3 do not sum to the value in Column 1 because of changes in revenue collected from housing transaction taxes, income taxes and estate tax.
transfers by exhausting financial resources after the exemption is decreasing in PI.

Column 4 presents the compensating variation and column 5 presents the ratio of this to the change in payments. This form of implicit insurance has both an income effect and targets insurance at states of the world with high marginal utility. Those with the highest consumption experience the largest drops when exposed to potentially catastrophic LTC expenses. This reform increases their exposure to the risk of high medical expenses associated with their spouse and increases the probability they rely on their housing wealth to finance future consumption or, even worse, see their whole portfolio spent on a spouse’s care. Consequently, the baseline policy offers substantially more insurance for their total wealth and households require large compensation to be indifferent to the reform. The per £1 valuation is larger than results for medicaid expansion found in De Nardi et al. (2016a) or Achou (2020) for samples of single US retirees. These studies, however, show a strong gradient in PI and the sample of married homeowners studied here have much larger wealth holdings on average. Furthermore, as highlighted by De Nardi et al. (2021), saving to insure surviving spouses are responsible for almost 30% of all US retiree wealth holdings - consistent with the large valuation of this policy. The valuations of this complete insurance are large in part because it almost fully indemnifies couples.\(^{31}\)

Table 10 eliminates the exemption on couples’ financial assets. This reform lowers the out-of-pocket share for LTC expenditures, as households are partially insured against potentially catastrophic costs. On average, the government expenditure declines by less than 40% of the full policy. Household valuations, column 4, fall by

\(^{31}\)LTC expenditures are exogenous, consistent with evidence on their income and price elasticities. This may lead to quantitatively larger welfare effects, but is unlikely to affect the qualitative findings.
Panel (a): the CV and change in PDV of government expenditures (analogous to columns 1 and 4 in Table 10). Panel (b): The ratio (analogous to column (5) in Table 10). Both panels vary the percentage exemption applied to Couples when one member of the household has LTC needs.

more than the change in expenses per initial owner and the per £1 valuation falls.

Both of these reforms consider inframarginal reductions in household insurance. Figure 8 shows how valuations for exemptions to household financial wealth vary with the size of the exemption and sign of the policy change. Per £1 valuations are decreasing in the size of the exemption offered. The additional value of offering some insurance far outweighs the limited cost this imposes on the government, but increasing insurance from the already generous status quo is less valuable. In addition, as it approaches full indemnity the moral hazard effect substantially increases government costs. This is because eliminating risk completely leads to greater distortions of household portfolios as they reduce liquid wealth holdings.

Why are the valuations for marginal liquidity large? Consider married retirees Kate and Will. They own a home, liquid savings of £50,000 and must finance his LTC expenditures. The existing policy caps Will’s LTC costs at £25,000. Kate has £25,000, the house and a reduced pension income after Will dies.

Without any exemptions on financial assets, Will’s LTC costs eliminate all liquid resources. Kate can keep their home and absorb the LTC expenses into non-housing consumption, but reduces future consumption and enjoys a severe decline in consumption today. Alternatively, she can sell her home, pay large adjustment costs, economize on housing services and bequests, but release liquid wealth for consumption. As discussed by Chetty and Szeidl (2007) and Kaplan and Violante (2014), households
may not find it optimal to adjust their housing stock in response to ‘small’ shocks. Non-adjusters exhibit excess sensitivity in their non-housing consumption, magnifying the welfare costs of shocks. Providing exemptions for liquid wealth creates a buffer which helps Kate avoid this dilemma and the large costs associated with it. Crucially, insuring only her housing wealth is not enough to allow her to remain in the house. Complementarity between housing and precautionary motives amplifies retirees’ valuation of liquidity because selling homes is costly. Increasing the generosity of the policy leaves Kate better off as it provides additional liquidity, but, importantly, is no longer providing the marginal liquidity to stay in their home.

9 Conclusion

This paper estimates a dynamic microeconomic model of consumption and housing choices during old age in the presence of health, LTC expense, mortality and house price risk. Combining data on wealth composition with tax policy changes in the UK facilitates separately identifying different motives for holding wealth. Estimation disciplined by data on future bequests reveals large differences in retirees’ preference for leaving bequests which is correlated with lifetime income and wealth.

Understanding the portfolio composition of retirees and how they trade-off liquidity and housing is key with model validation reproducing causal evidence from notches in the housing transaction tax schedule. Demand for liquidity drives differences in the response to windfalls in retirement wealth. When house prices increase downsizing becomes more attractive whereas pension windfalls lower the attractiveness of downsizing. This leads to differences among marginal downsizers; generating a lower aggregate marginal propensity to bequeath from house price shocks, even though in both cases older generations share their good fortune with future generations.

Finally, I address how means-testing in the provision of LTC benefits treats different asset classes. I concentrate on a feature of publicly provided LTC benefits which confers additional insurance to the assets of couples. When the elderly want to remain in their home the value of this insurance is important. Insuring only housing assets is often insufficient to allow a healthy spouse to remain in the home. Thus, insuring marginal liquid wealth is most valuable and designing means-testing with portfolios in mind is a fruitful avenue for future work.

This paper leverages features of the UK institutional context to identify and quan-
tify savings motives. The results offer important lessons for the well being of retirees and the design of public programs around the world. With rising house prices and ageing populations it is essential to understand housing’s role in old age.

References


Appendix For Online Publication

A Inferring Permanent Income

I infer household level measures of permanent income that is invariant to the household structure so that it is fixed across demographic transitions. Individual non-labour income is the sum of state pension income, private pension income, annuity income, war pensions, widows pensions and any other declared non-labour income. It excludes employment, self-employment income and asset returns. Other than state pensions it does not include benefit income (which are part of the tax function in the model). For singles income is the same as individual income and for couples it is the sum across husband and wife. Following De Nardi et al. (2021), I assume log household income for household $i$ at age $j$ follows:

$$\ln y_{i,j} = f(j, f_{it}) + h(I_i) + e_{i,j}$$ (A.1)

where $f(\cdot)$ is a flexible function of age and family structure and $I_i$ is their time invariant permanent income (PI). In practice I estimate the following fixed effect regression to obtain consistent estimates of $f(\cdot)$:

$$\ln y_{i,j} = f(j, f_{it}) + \gamma_i + e_{i,j}$$ (A.2)

For each household the estimated vector of coefficients is used to compute the mean residual (or the estimate of their fixed effect) $\hat{\gamma}_i$ which is consistent as the number of periods a household is observed becomes large. $\hat{I}_i$ is computed as the percentile rank of $\hat{\gamma}_i$. The final step is to estimate:

$$\ln y_{i,j} - f(j, f_{it}) = h(I_i) + e_{i,j},$$ (A.3)

which recovers the mapping from the PI index to the log of household income. In practice, I use a third order polynomial in age $j$, dummies for family structure and interactions with a linear trend in age to estimate $f(\cdot)$. $h(\cdot)$ is a fifth order polynomial in estimated PI $\hat{I}_i$. 
(a) Mean Total Wealth (Main Text Cohorts) (b) Mean Total Wealth (Additional Cohorts)

Figure A.1: Total Wealth by Cohort (Initial Owners)

Each line shows a cohort-PI cell over the period 2002-2014, plotted against average cohort ages. Thicker lines denote higher PI groups.

B Additional Key Facts

Figure A.1 displays average total wealth for the cohorts presented in the main text (Panel a) and the remaining birth cohorts (Panel b). As with the discussion of housing wealth in the main text and below, there is evidence of a common aggregate trend. This leads to increasing wealth in the early waves and slowly declining wealth thereafter for all PI groups. As discussed elsewhere, this is driven by the cyclicality of housing wealth. Liquid wealth does not display the same cyclicity. As gaps in both types of wealth accumulate, total wealth shows the largest PI gradient with substantial heterogeneity along PI dimensions. This PI heterogeneity is larger than the effect of within cohort ageing (with the exception of the youngest cohort in panel b which are discussed below).

B.1 Housing Wealth

Figure A.2 reproduces Figure A.2 in the main text for the remaining birth cohorts. Although the key facts remain when considering alternative cohorts, housing wealth in panel (a) shows two apparent differences. First, the housing wealth of the highest PI households appears more volatile. Second, the youngest cohort do not at first glance appear to follow the same aggregate trend. However, this cohort ages into the sample fours years later at the peak of UK houseprices.
(a) Mean Housing Wealth by Cohort (b) Frequency of moves in the last 2 years

Figure A.2: Saving in Housing Wealth by Cohort (Initial Owners, Additional Cohorts)

Panel (a): Each line shows a cohort-PI cell over the period 2002-2014, plotted against average cohort ages. Thicker lines denote higher PI groups. Panel (b): cohort cells for the same period.

B.2 Liquid Wealth

Figure A.3 displays average liquid wealth for the alternative cohorts. As with the cohorts in the main text, there is some evidence of deaccumulation among initial owners and differences between the top PI quartile and the 2nd group exceed differences between the 2nd quartile and bottom 50% of the PI distribution. There are signs of accumulation by initial owners, but this is small in absolute terms.

C Policy details

Table A.1 documents the thresholds and rates for SDLT throughout the sample period. The final column indicates how different tax policies are implemented in the model. Due to the two year time period in the model (to match the ELSA data), and to keep estimation computationally feasible, I pool the March 2005 reform with the March 2006 reform. The “Stamp Duty Holiday” was originally scheduled to end in September 2009 before being extended in April of that year. I treat this April extension and eventual reversal as known ex-ante. One important feature of the variation in SDLT over the time period is that it effects households across the wealth distribution with reforms at both the upper and lower ends of the housing wealth distribution. Households elsewhere in the distribution also interact with this tax system as price fluctuations move them across thresholds.
Figure A.3: Mean Liquid Wealth by Cohort (Additional Cohorts)

Panel (a): Each line shows a cohort-PI cell over the period 2002-2014, plotted against average cohort ages. Thicker lines denote higher PI groups. Panel (b): cohort cells for the same period.

<table>
<thead>
<tr>
<th>Effective from</th>
<th>1%</th>
<th>3%</th>
<th>4%</th>
<th>5%</th>
<th>7%</th>
<th>Regime</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 March 2000</td>
<td>£60</td>
<td>£250</td>
<td>£500</td>
<td>N/a</td>
<td>N/a</td>
<td>I</td>
</tr>
<tr>
<td>17 March 2005</td>
<td>£120</td>
<td>£250</td>
<td>£500</td>
<td>N/a</td>
<td>N/a</td>
<td>II</td>
</tr>
<tr>
<td>23 March 2006</td>
<td>£125</td>
<td>£250</td>
<td>£500</td>
<td>N/a</td>
<td>N/a</td>
<td>II</td>
</tr>
<tr>
<td>03 September 2008a</td>
<td>£175</td>
<td>£250</td>
<td>£500</td>
<td>N/a</td>
<td>N/a</td>
<td>III</td>
</tr>
<tr>
<td>01 January 2010</td>
<td>£125</td>
<td>£250</td>
<td>£500</td>
<td>N/a</td>
<td>N/a</td>
<td>IV</td>
</tr>
<tr>
<td>06 April 2011</td>
<td>£125</td>
<td>£250</td>
<td>£500</td>
<td>£1,000</td>
<td>£2,000</td>
<td>V</td>
</tr>
</tbody>
</table>

Table A.1: Rates and Thresholds for Stamp Duty Land Tax

All thresholds and rates refer to transactions of residential property. During the time period there are additional exemptions for disadvantaged areas. \(^a\) denotes the “Stamp Duty Holiday” where the 0% rate threshold was temporarily extended.
The reform to Estate Taxation, which was backdated indefinitely, described in Section 3 came with little warning. Consequently, I assume no anticipation. Model regimes I-II use the original tax treatment while III-V use the new threshold. Strictly, the reform depends on bequests disbursed at death of the first partner. However, to avoid introducing additional state variables (and consistent with the model) I assume this doubles the effective threshold at death of the final spouse. This in line with the effective change to the policy for the majority of older households in ELSA. Crawford and Mei (2018) report that nearly all wealth is left to a surviving partner, if one exists, alleviating the impact of incomplete histories. Typically, the never-married or divorced retirees have lower savings and the original threshold is non-binding. Thus, this simplification introduces minimal error in tax incentives. Figure A.1, shows the mean wealth holdings in the top 50% of the PI distribution are near or above the original exemption rate, suggesting the reform is empirically relevant.

D Additional RDD results

A key concern in RDD estimation is the manipulation of the forcing variable. Conventional tests for manipulation (McCrary, 2008) overreject when the forcing variable is discrete. Figure A.4a plots the distribution of self assessed house values and shows that their support has a number of mass points. Mass points are not themselves evidence of manipulation and there is no evidence of missing mass to the right of the threshold - missing mass here would be consistent with manipulating self assessed house values reported to ELSA. Furthermore, the distribution around the transaction tax threshold is similar to other windows.

Nevertheless, a concern is that the sparsity of the underlying distribution may lead to bias in statistical inference. Figure A.4b shows the results from placebo tests applying the same estimation to artificial thresholds evenly spaced at £10,000

---

1The BBC described events as:

Chancellor Alistair Darling has doubled the inheritance tax threshold for married...But he was accused by the Tories - who unveiled policies in all these areas last week - of being in a “panic” after their recent opinion poll surge.

Source: [http://news.bbc.co.uk/2/hi/uk_news/politics/7034399.stm](http://news.bbc.co.uk/2/hi/uk_news/politics/7034399.stm)

2The distribution suggests households have a tendency to report round numbers - a form of non-classical measurement error. Battistin et al. (2009) show that as long as non-classical measurement error is orthogonal to the process of interest then the regression discontinuity design still identifies the parameter of interest.
Panel (a): The distribution of self assessed house values for the sample population. The vertical dashed red line indicates the transaction tax threshold. Panel (b): Placebo tests for alternative artificial transaction tax thresholds using the quadratic specification described in the main text.

intervals. Only the coefficient using the true transaction tax threshold is significant and sparsity does not generate false significance at placebo thresholds. Additional results for confidence intervals with guaranteed coverage properties are below.

In addition to checking for manipulation, I directly test for the smooth distribution of additional covariates by estimating the main specification with alternative covariates as the outcome variable. Table A.2 reports the treatment effect for four variables that economic theory predicts affects household moving decisions. The first two columns show there is no statistically significant discontinuity in total (or liquid) resources around this threshold. Likewise column 3 shows age varies smoothly across the transaction tax threshold. The final column shows there is a small, statistically

<table>
<thead>
<tr>
<th>Total Wealth (100,000s GBP)</th>
<th>Liquid Wealth (100,000s GBP)</th>
<th>Age (Years)</th>
<th>Permanent Income (0 to 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.0568</td>
<td>-0.0568</td>
<td>0.0382</td>
<td>-0.0411**</td>
</tr>
<tr>
<td>(0.0868)</td>
<td>(0.0868)</td>
<td>(0.458)</td>
<td>(0.0191)</td>
</tr>
</tbody>
</table>

All regressions use a second order polynomial in housing wealth and additionally control for wave fixed effects, household demographics, and region dummies. Standard Errors are clustered by household. N=3979 throughout. * p < 0.10, ** p < 0.05, *** p < 0.01

Table A.2: Covariate Balance around Transaction Tax Thresholds
significant reduction in household PI which falls by 4 percentage points. Those to
the left of the threshold have an average PI rank at the 60th percentile. While it is
unlikely that such a small decline generates the behaviour of interest (the sign of the
effect predicted by economic theory is ambiguous), I condition on PI throughout to
avoid this potential confounder.\footnote{The effect on estimated parameters of including this additional control is minimal.}

Table A.3 presents alternative specifications from the regression discontinuity esti-
mation of the effect of transaction taxes on the mobility of older household described
in Section 3 as well alternative inference.

<table>
<thead>
<tr>
<th>Panel A: Higher Order Polynomials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order of polynomial</td>
</tr>
<tr>
<td>Linear</td>
</tr>
<tr>
<td>Common Slope</td>
</tr>
<tr>
<td>Parametric</td>
</tr>
<tr>
<td>Linear</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Cubic</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Quartic</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>N</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B: Bounded Second Derivative Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoothness (K)</td>
</tr>
<tr>
<td>Local Linear</td>
</tr>
<tr>
<td>BSD CI</td>
</tr>
<tr>
<td>Implied Bandwidth</td>
</tr>
<tr>
<td>Significance Level</td>
</tr>
<tr>
<td>Eff. Sample Size</td>
</tr>
</tbody>
</table>

All regressions additionally control for wave fixed effects, a polynomial in age, household
demographics, a polynomial in permanent income and region dummies. Following Kolesár and
Rothe (2018), Standard Errors in panel A are clustered by household. The Akike Information
Criterion is shown in italics. In panel B the implied bandwidth is the one that minimizes the
length of the resulting CI for a given choice of K. * \( p < 0.10 \), ** \( p < 0.05 \), *** \( p < 0.01 \)

Table A.3: The Effect of Transaction Taxes on Household Mobility

Panel A shows the robustness of the common slope estimates to alternative order
polynomials. First, the linear specification is more sensitive to the size of the band-
with chosen than the specification in the main text. For the smallest band around
the cut-off value the result using a quadratic specification are of a similar magnitude
to the linear specification, but estimated with less precision. Using both the cubic
and quartic estimators the estimated treatment effect remains negative for all band-
widths and is significant for larger bandwidths around the discontinuity in the SDLT schedule. The results are consistent with the lower order polynomial and local linear estimates presented in the main text. Gelman and Imbens (2017) caution over using higher-order global polynomials due to noisy estimates, sensitivity to the degree of the polynomial and poor coverage of confidence intervals. While the results here demonstrate some of these problems, nevertheless the point estimates are similar to those obtained with lower order polynomials and non-parametric methods (particularly over the largest estimation window). This suggests estimated treatment effects are not driven by the approximation of the conditional expectation function.

House values have an underlying discrete support (Figure A.4a). In the baseline analysis, tests of statistical significance use standard errors clustered at the household level. As recommended by Kolesár and Rothe (2018) they are not clustered at values in the support of the forcing variable (Lee and Card, 2008, motivates this adjustment). When resulting model misspecification bias is large these confidence intervals undercover the true average treatment effect. This is especially concerning when large bandwidths are used or the discrete support leads to insufficient observations in a small neighbourhood of the threshold.

To assess the robustness of results to these concerns, Panel B in A.3 uses an alternative method (see Kolesár and Rothe, 2018) to construct confidence intervals with guaranteed coverage properties. Implementing this method requires that a smoothness constant $K$ (a bound on the second derivative of the conditional expectation function with $K = 0$ indicating it is known to be linear) is chosen.

Column 1-5 report confidence intervals for $K \in \{0.001, 0.01, 0.02, 0.1\}$, representing a range of smoothness parameters ranging from ‘optimistic’ to ‘pessimistic’ choices (central values sandwich a lower bound estimate $K = 0.012$). Each column reports bias corrected point estimates using a local linear estimator with optimal bandwidth for fixed smoothness constants and classes. Resulting confidence intervals are reasonably tight and are close to those reported in Table 2. The null hypothesis of 0 effect is rejected at the 5% significance level for all but the most pessimistic value of $K$. Even for this extreme case a 90% confidence interval excludes 0.4

4Although this is not analogous to a one-sided test it is also the case that the null hypothesis of a weakly positive treatment effect is rejected at the 5% significance level.
(Un)Collateralized Borrowing by the Elderly

I rule out collateralized and uncollateralized borrowing for three reasons. First, 95% of older households have paid off their mortgage or have positive liquid wealth balances. Second, many retired households fail to meet the income requirements of traditional forward mortgages and in the data very few retired households take out new mortgages to upsize. Third, although reverse mortgage products do exist the UK market is small - a common international trend. Finally, the UK market is tightly controlled on negative equity where the total value of the mortgage is still required to be paid in full which lowers the demand for equity release.

Davidoff et al. (2017) documents that limited financial literacy of potential product users contributes to the low take up of reverse mortgages in the US. Two major mortgage retailers offered home equity release products in the UK between 1996 and 1998 as shared appreciation schemes (where home owners are insured against falls in house prices, but own progressively less of the equity in their home when prices rise). These shared appreciation schemes were subject to limited financial regulation and were the subsequent target of extensive negative press coverage and a class action lawsuit. This likely persistently depresses demand for equity release products.

Renter’s Problem

The renter’s problem \( (h' = 0) \), renting housing services \( \bar{h} \) at price \( r^h p_h \), is:

\[
V_i^j(\Omega) = \max_{\{c, a'\}} \left\{ u(f, c, \bar{h}) + \beta \cdot \eta(j, I, m, f) E[V_{i+1}^j(\Omega') | \Omega, h' = 0, a'] \right. \\
+ \beta(1 - \eta(j, I, m, f)) E[\phi'(b) | \Omega, h' = 0, a'] \right\}, \tag{A.4}
\]

subject to equations (2)-(9), (A.5)-(A.6), (14)-(17) and bequests constrained by equation (18). Renting housing services implies modified constraints:

\[
x_{t+1} = x_t - c_t - r^h p_{h,t} \bar{h}_t - Q(0, h_t, p_{h,t}) - m x_{t+1} + \tau_y \left( r a_{t+1} + y_{t+1}, f_{t+1}, \tau \right) + \tau r_{t+1} \tag{A.5}
\]

\[
a_{t+1} = x_t - c_t - r^h \bar{h}_t p_{h,t} - Q(0, h_t, p_{h,t}) \geq 0, \quad \forall t. \tag{A.6}
\]


G Method of Simulated Moments

The estimated parameters are defined by minimizing the weighted distance between data moments and model generated moments for a given parameter vector:

\[
\hat{\theta} \arg \min_{\theta \in \Theta} G(\vartheta, \theta)'WG(\vartheta, \theta),
\]

which takes the form of a standard GMM objective function. This differs from equation (20) as here moment conditions depend explicitly on both \(\vartheta\) and \(\theta\) the vectors of first and second stage estimates respectively. \(W\) is the inverse-diagonal weighting matrix proposed by Pischke (1995) as the asymptotically optimal weighting matrix suffers from finite sample bias (Altonji and Segal, 1996).

The dynamic programming problem described in Section 4 does not admit closed form analytic solutions and I use numerical methods described in Appendix K to compute optimal policies and simulate household decisions. This is a standard approach (see, for example, Gourinchas and Parker, 2002). Given the optimal household decisions for a given set of parameter values and household initial conditions drawn from the data, I simulate forward households through the different policy regimes drawing values of \(\epsilon_{mx}\) from their distribution using Monte Carlo methods. I then construct moment conditions from this simulated data in the exact same way as in the data - this forms the basis of my estimation procedure.

To construct moment conditions, I calculate model implied ‘objective’ probabilities as the equivalent of subjective probabilities in ELSA provided on a 101 point (0-100) percentage scale. The question I match is

Including property and other valuables that you [and your husband/wife/partner] might own, what are the chances that you [and your husband/wife/partner] will leave an inheritance totalling £150,000 or more?

This assumes self-reported probabilities accurately summarize optimal future behaviour given a household’s current information set. This is common when expectations about future behaviour are used in combination with contemporaneous choice data (e.g. van der Klaauw and Wolpin, 2008; van der Klaauw, 2012).

Using conditional means as moment conditions requires the model matches the full distribution of wealth holdings well because a household’s total wealth rank and PI are positively correlated. I winsorize wealth moments in both data and simulations at
the 95th percentile. This mitigates the impact of the very wealthy and other potential sources of measurement error. I use 7 five year birth cohorts and 3 PI groups. Data versions of these moments are presented in Section 2 and I use identical operations to calculate simulation equivalents.

I simulate 150,000 sample households and draw initial state variables from the empirical joint distribution in the ELSA data. Simulated counterparts remain in the simulation sample for the duration that their ELSA donor remains in the ELSA sample and receive their donor’s sequence of exogenous state variables. This defines a calendar time window including reforms to Inheritance Tax and transaction taxes (SDLT) and house price changes experienced by their ELSA donor. This procedure perfectly replicates any compositional changes in the sample as they age and die as well as the sequence of time effects through aggregate house price changes and policy reforms (including arbitrary realized correlation).

To summarize, I match mean liquid wealth, housing wealth, bequest probabilities, mobility rates, and homeownership rates by birth cohort, age and conditional on PI and initial ownership status. Matching moments by average age conditional on birth cohort is equivalent to matching the ELSA data by wave. Let \( q_{i,t} \) denote a data quantity for household \( i \) at time \( t \) and \( ar{q}_{c,p,o,t} (\vartheta, \theta) \) denote the model predicted average quantity for simulated households in cohort \( c \), PI group \( p \), initial housing tenure \( o \) at time \( t \). Moment conditions can then be expressed as:

\[
E([q_{i,t} - \bar{q}_{c,p,o,t}(\vartheta, \theta)] \times 1[c_i = c] \times 1[I_i \in \mathcal{P}_p] \times 1[o_i = o] \times 1[i \text{ observed at } t]|t), \quad (A.8)
\]

for \( c \in \{1910, 1915, 1920, 1925, 1930, 1935, 1940\} \), \( o \in \{\text{owner}, \text{renter}\} \), \( p \in \{1, 2, 3\} \), and \( t \in \{2002, 2004, ..., 2014\} \). \( \mathcal{P}_p \) defines the values contained in the \( p \)th PI group. In addition, each cohort-income-ownership-age cell must have at least 15 observations to be included in the GMM criterion. In total there are 410 target moments.

Let \( N \) denote independent households that are each observed at up to \( T \) separate calendar years. \( G(\vartheta, \theta) \) denotes the \( J \)-element vector of moment conditions described immediately above, and \( \hat{G}_N(\vartheta, \theta) \) denotes its sample analog. Letting \( \hat{W}_N \) denote the \( J \times J \) weighting matrix, computed as the inverse-diagonal of the sample analog\(^5\) to

\(^5\)I use the observations in each cell, \( N_{c,p,o,t} \), instead of \( N \) to calculate diagonal elements of \( \hat{W}_N \).
the optimal asymptotic weighting matrix, the MSM estimator $\hat{\theta}$ is implemented as:

$$\arg\min_{\theta \in \Theta} \hat{G}_N(\vartheta, \theta)' \hat{W}_N \hat{G}_N(\vartheta, \theta).$$

(A.9)

In practice, $\vartheta$ is also estimated, however, computational concerns necessitate treating it as known throughout the analysis that follows. Under the regularity conditions stated in Pakes and Pollard (1989) and Duffie and Singleton (1993), the MSM estimator $\hat{\theta}$ is both consistent and asymptotically normally distributed:

$$\sqrt{N} (\hat{\theta} - \theta_0) \overset{d}{\rightarrow} N(0, V),$$

with the variance-covariance matrix $V$ given by

$$V = (1 + \tau)(D'WD)^{-1} D'WSWD(D'WD)^{-1},$$

where $S$ is the variance-covariance matrix of the data; $\tau$ is the ratio of the number of observations to the number of simulated observations;

$$D = \left. \frac{\partial G(\vartheta, \theta)}{\partial \theta'} \right|_{\theta = \theta_0}$$

(A.10)

is the $J \times M$ gradient matrix of the population moment vector; and $W = \text{plim}_{N \to \infty} \{ \hat{W}_N \}$. $D$, $S$, and $W$ are estimated by their sample analogs. When estimating $S$, I use sample statistics, replacing $\bar{q}_{c,p,o,t}(\vartheta, \theta)$ by the sample mean for group $c, p, o, t$.

H Additional Estimation Details

This appendix summarizes first stage parameter estimates or calibrations not in the main text as well as providing more detail on how health and mortality are estimated. Table A.4 summarizes data sources and first stage parameter values.

The Utility Function The consumption equivalence scale is set using the OECD modified scale (estimates for retirees in De Nardi et al., 2021, are almost identical).

The Housing Market Annual depreciation, $\delta$, is set at 2% (Cocco and Lopes, 2020) and the rental cost is 3.94% of the sale price (Jordà et al., 2019). I estimate the
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>Consumption Equivalence Scale</td>
<td>1.5</td>
<td>OECD Modified Scale</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Housing Maintenance Costs</td>
<td>0.02</td>
<td>Cocco and Lopes (2020)</td>
</tr>
<tr>
<td>$r_h$</td>
<td>Rental Cost</td>
<td>3.94%</td>
<td>Jordà et al. (2019)</td>
</tr>
<tr>
<td>$\rho_h$</td>
<td>House Price AR(1) persistence</td>
<td>0.977</td>
<td>HM Land Registry</td>
</tr>
<tr>
<td>$\mu_h$</td>
<td>House Price Drift</td>
<td>0.019</td>
<td>HM Land Registry</td>
</tr>
<tr>
<td>$\sigma_h$</td>
<td>House Price S.D. Innovations</td>
<td>0.095</td>
<td>HM Land Registry</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>Incidence of SDLT on Seller</td>
<td>0.4</td>
<td>Besley et al. (2014)</td>
</tr>
<tr>
<td>$r$</td>
<td>Risk Free Return</td>
<td>3.0%</td>
<td>Bozio et al. (2017)</td>
</tr>
<tr>
<td>$y(\cdot)$</td>
<td>Deterministic Income Profile</td>
<td></td>
<td>ELSA</td>
</tr>
<tr>
<td>$\tau_y$</td>
<td>Income Tax Function</td>
<td>Table A.5</td>
<td>TAXBEN</td>
</tr>
<tr>
<td>$c_{\min}$</td>
<td>LTC consumption floor (Singles)</td>
<td>£2,679</td>
<td>Ameriks et al. (2011)</td>
</tr>
<tr>
<td>$\eta(\cdot)$</td>
<td>Survival Probabilities</td>
<td></td>
<td>ELSA</td>
</tr>
<tr>
<td>$Pr(m_{j+1}^y</td>
<td>\cdot)$</td>
<td>Health status</td>
<td></td>
</tr>
<tr>
<td>$\mu_{mx}(\cdot)$</td>
<td>Mean LTC Expenses</td>
<td></td>
<td>HRS</td>
</tr>
<tr>
<td>$\sigma_{mx}(\cdot)$</td>
<td>Conditional variance LTC Expenses</td>
<td></td>
<td>HRS</td>
</tr>
</tbody>
</table>

All values are annual and expressed in 2014 prices.

Table A.4: 1st Stage Parameter Estimates

time series process for house prices using OLS and data from the HM Land Registry UK house price index series. The estimation sample uses data from all regions in England and normalizes December 2002 house prices to 1. House prices are highly persistent, drift upwards, and innovations with a large variance. Parameter values are in table A.4. Transaction tax incidence is taken from Besley et al. (2014).

**The Budget Constraint** I calibrate returns on the risk free asset, $r$, at 3% (Bozio et al., 2017). Non-asset pension income profiles are estimated directly from ELSA using the procedure described in Appendix A. Income taxes are approximated by a modified version of a common log-linear functional form (e.g. Feldstein, 1969) with after tax income given by

$$\bar{y} = \bar{y} + \lambda_y y^{1-\tau_y},$$

where $\lambda_y$ controls the level of taxation, $\tau_y$ controls progressivity and $\bar{y}$ captures features corresponding to an income floor. I estimate this separately for couples and singles. I combine data from TAXBEN, a microsimulation model of the UK tax and benefit system (see Waters, 2017, for further details), with individual household data for my ELSA sample in order to estimate the tax function. This includes taxes and
Table A.5: Tax Function Parameter Estimates

<table>
<thead>
<tr>
<th></th>
<th>$\bar{y}$</th>
<th>$\lambda_y$</th>
<th>$\tau_y$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singles</td>
<td>556</td>
<td>99.1</td>
<td>0.468</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>(737)</td>
<td>(24.8)</td>
<td>(.0213)</td>
<td></td>
</tr>
<tr>
<td>Couples</td>
<td>5,083</td>
<td>7.62</td>
<td>0.213</td>
<td>0.927</td>
</tr>
<tr>
<td></td>
<td>(819)</td>
<td>(2.32)</td>
<td>(0.0262)</td>
<td></td>
</tr>
</tbody>
</table>

both means-tested and universal benefits, but excludes coverage of social care costs.\(^6\)

Table A.5 reports parameters estimated by non-linear least squares. Despite its parsimony, $R^2$ values show this accurately predicts after tax and transfer income.

**Mortality and Health Transitions** I define the worst health status as difficulties with two or more Activities of Daily Living (ADL) capturing both mortality and medical expenditure effects in a parsimonious manner. Each wave, household members are asked about difficulties in six different categories of activities:

1. difficulty dressing, including putting on shoes and socks
2. difficulty walking across a room
3. difficulty bathing or showering
4. difficulty eating, such as cutting up food
5. difficulty getting in and out of bed
6. difficulty using the toilet, including getting up or down

This is intended to capture the minimum range of daily activities typically performed by the adult population and proxy an individual’s ability to live independently. Each individual’s health status, $m^9$, has four possible values enumerated as follows:

$$m = \begin{cases} 
0 & \text{Good Health} \\
1 & \text{Bad Health} \\
2 & \text{ADL Limitations} \\
3 & \text{Dead} 
\end{cases}, \quad (A.11)$$

---

\(^6\)This is not included in the tax function as its means-testing is explicitly modeled.
with transition probabilities depending on current health, age $j$, family structure $f$, PI $I$, and gender $g$.\textsuperscript{7} Elements of the health transition matrix are given by

$$\pi_{i,q,p}(j, f_{it}, I_{i}, g) = \Pr \left( m_{i,j+2}^q = q \mid m_{i,j}^q = p; j, f_{it}, I_{i}, g \right),$$

(A.12)

where transitions span the two year interval of the ELSA data. These transition probabilities are estimated by fitting a multinomial logit model to observed transitions. This gives the following expression for health and mortality transitions

$$\pi_{i,q,p}(j, f_{it}, I_{i}, g) = \frac{e^{x_{it}\beta_q}}{\sum_{h=0}^{3} e^{x_{it}\beta_h}},$$

(A.13)

where $\beta_q$ denotes the coefficient vector for next period outcome $q$. Health transitions and survival probabilities are jointly estimated at the individual level using a maximum likelihood estimator. The vector of covariates $x_{it}$ includes age, sex, current health status, marital status, and PI. Specifically, a third order age polynomial, indicators for gender and marital status (interacted with a linear age trend), an indicator for single man interacted with PI, contemporaneous indicators for health (interacted with age, gender and PI), and a quadratic in PI (interacted with a linear age trend and marital status). In total this gives 25 parameters in each $\beta_q$ coefficient vector. Table 3 summarizes simulated histories using estimated transition probabilities.

**Long Term Care Costs** Due to the paucity of UK data I use comparable data from the HRS to estimate the LTC expense process - effectively imputation. I construct the HRS data identically to the ELSA data to replicate sample selection.

The HRS medical spending measure is the sum of expenditures paid out-of-pocket plus those paid by Medicaid (See De Nardi et al., 2021, for details on this construction) capturing total costs incurred by private individuals and the government. This is the relevant measure as the model incorporates means-tested government payments that would be covered by Medicaid in the US. This measure is backwards looking, hence $m_{x_j}$ captures the flow of LTC expenses between $j - 1$ and $j$. Equations (7) and (??) outline this process. I estimate $\mu_{m_{x_j}}(\cdot)$ and $\sigma_{m_{x_j}}(\cdot)$, by writing Equation (7) as

$$\ln m_{x_{it}} = x_{1i}\beta_1 + x_{2it}\beta_2 + \vartheta_i + \varsigma_{it},$$

(A.14)

\textsuperscript{7}Health transitions are independent of medical spending. Empirical evidence on whether medical spending improves health at older ages is inconclusive in part due to reverse causality.
where $x_{1i}$ denotes a vector of time-invariant variables, $x_{2it}$ denotes a vector of time-varying variables, $\vartheta_{i}$ is an unobserved person-specific term, and $\varsigma_{it}$ captures any remaining variation. I assume $E(\varsigma_{it} | \vartheta_{i}) = 0$.

I estimate Equation (A.14) in three steps. First, regressing log medical spending on the time-varying factors in Equation (A.14), namely age, household structure, and health, and interaction terms (such as gender and PI interacted with the time varying variables) using a fixed effects estimator. Specifically, I regress log medical spending on an age quadratic (the linear trend interacted with PI), indicators for single man and single woman (interacted with an age trend), the contemporaneous and lagged values of indicators for health status, whether the man died (interacted with PI), whether the woman died (interacted with PI). Including current and lagged family structure indicators accounts for the jump in medical spending at the death of a family member and including health indicators for both periods distinguishes persistent from transitory health episodes.

As fixed effects regression cannot identify the effects of time-invariant factors, which are subsumed into the estimated fixed effects, the second step collects the residuals from the first regression, including estimated fixed effects, and regresses them on the time-invariant factors: a quadratic in PI and a set of cohort dummies.

A key feature of this spending model is that both the conditional variance and the conditional mean of medical spending depends on demographic and socioeconomic factors, through the function $\sigma(\cdot)$. The third step estimates $\hat{\mu}_{mx}(\cdot)$ to back out the residual $\epsilon$ from Equation (7). To find $\hat{\sigma}^2(\cdot)$, residuals are squared and regressed on the demographic and socioeconomic variables in Equation (7).

When including this estimated process in the model, I impose 0 costs unless a member of the household is in the ADL state. I do not impose this in estimation, using information about the relationship between demographic and socioeconomic characteristics and medical spending in all health states of the HRS to ameliorate limited sample size across age, PI, and family structure cells in the ADL state.

**Latent Types** I recover the bequest preference index by estimating:

$$y_{i,t} = \beta X_{i,t} + f(W_{i,t}^{liquid}, W_{i,t}^{housing}) + \lambda_t + \gamma_i + u_{i,t} \quad (A.15)$$
where the dependent variable is their subjective bequest probability and I control for total wealth by allowing for within wave quintile specific effects. Quintile specific effects impose limited restrictions on the underlying function and I control separately for home ownership and the housing wealth share. I control for contemporaneous characteristics of the household with time $t$ period controls for age, household income, gender, marital status, health for all household members, subjective survival probabilities, and vital statistics of their parents as well as wave fixed effects.\footnote{Wave specific effects are necessary because survey questions refer to a fixed nominal threshold.} Finally, the object of interest is a household specific fixed effect $\gamma_i$. Additionally, I residualize on time invariant PI and birth cohort dummies.

I place no direct interpretation on the coefficients or fixed effects recovered by this regression, instead viewing it as a statistical exercise designed to capture systematic differences across households. Estimated fixed effects, $\hat{\gamma}_i$, are noisy measures, but potentially informative of future behaviour. This is similar to using heterogeneity in stated intention to save for a bequest (see Laitner and Juster, 1996) or reason for saving (Favilukis et al., 2017, use the Survey of Consumer Finances to calibrate binary bequest motive heterogeneity generating wealth inequality).

Marginal distributions of household characteristics, $z_i$, by household types are displayed in figures A.5a to A.5c with mean values denoted by dashed vertical line. This provides a succinct description of how the $k$-means clustering algorithm partitions household’s based on their characteristics. These results offer a more complete characterisation than the summary statistics provided in Table 4. The full distributions reflect the comparisons of group means. However, as clustering uses multiple dimensions the supports in any given dimension are not exclusive.

When using the $k$-means clustering approach, the researcher is left with two degrees of freedom: a) which variables to use to cluster the households and b) the number of clusters.\footnote{It is also necessary to specify cluster initialization, however, I use a multi-start algorithm where the initial assignment of clusters across households is drawn from $10,000$ random seeds.} The choice of variables to cluster on is motivated by the economic problem agents face and is discussed in more detail in Section 6 and I choose the number of clusters following heuristic methods in machine learning. Indexing the problem by a given number of clusters $K$:

$$\min_{\mathcal{K}, \{\bar{z}_k\}_{k=1}^K} \text{SSE}_K \quad \text{where} \quad \bar{z}_k = \frac{1}{N_k} \sum_{k(i)=k} z_i, \quad \mathcal{K} = \{k(i)\}_{i=1}^n$$

\hfill (A.16)
(a) PI Across Groups

(b) Total Wealth Across Groups

(c) Bequest Probability Index Across Groups

(d) Optimal Cluster Heuristic (Elbow Method)

Figure A.5: Additional Clustering details
the optimal number of clusters $K$ minimises this objective function without ‘overfitting’. As within cluster dissimilarity (the Sum of Squared Errors) is decreasing in the number of clusters $K$, which precludes cross-validation techniques, heuristics use the following intuition: suppose there is a true number of clusters $K^*$. For $K < K^*$ the algorithm assigns a subset of the true groups to each cluster. Increasing the number of clusters allows the algorithm to assign groups in a subset to a new cluster. Then increasing the number of clusters if $K < K^*$ leads to a large decrease in the measure of within cluster dissimilarity. In contrast, when $K > K^*$ one of the clusters partitions a true group into two spurious clusters. Consequently, the decrease in within cluster dissimilarity must be smaller.

Figure A.5d plots the Sum of Squared Errors ($SSE_K$) against the number of clusters a commonly used heuristic method for identifying this kink point: the ‘Elbow statistic’. Visual inspection identifies a kink at $K = 4$, which partitions the data into transparent groups while maintaining computational tractability.

I Computing the Bequest Share

To simplify discussion, I present bequest allocations when a household faces certain death in the following period. To do so, I compute the solution to the following static allocation problem for a single retiree renting housing:

$$\max_{c,s} u(f, c, s) + \beta \phi(b) \quad \text{s.t.} \quad c + s + b = x$$  \hspace{1cm} (A.17)

I solve the problem expressed in terms of expenditures, $e$, under unit house prices and abstract from LTC costs. The indirect utility function is given by:

$$u^e(e) = \frac{e^{1-\gamma}}{1-\gamma} \times \left[ \frac{1}{\sigma} \left( \frac{1-\sigma}{r^h} \right)^{1-\gamma} \right] = \frac{e^{1-\gamma}}{1-\gamma} \times \bar{u},$$  \hspace{1cm} (A.18)

and the allocation between within period expenditures and bequests solves:

$$\max_{e \leq x} u^e(e) + \beta \phi(x - e)$$  \hspace{1cm} (A.19)

The solution to this problem characterises the marginal propensity to bequeath and the threshold level of consumption above which bequests are operative. Interior so-
lutions have the following expression for the marginal propensity to expend:

\[ MPE = \frac{\bar{\phi}}{1 + \phi} \quad \text{where} \quad \bar{\phi} = \left( \frac{\beta \phi_1}{\bar{u}} \right)^{-\frac{1}{\gamma}}, \]  
(A.20)

and the threshold value of final period wealth above which bequest motives become operative (or the annuity value of consumption) is given by:

\[ c_{\text{beq}} = \bar{\phi} \times \phi_2. \]  
(A.21)

Finally, Figure 5 requires homogenizing estimates across studies. Only Nakajima and Telyukova (2020) estimate a model with housing. For the remaining studies I use this paper’s estimated \( \sigma \) to calculate \( \bar{u} \) while using their own estimate of the coefficient of relative risk aversion, \( \gamma \). This generates minor differences between reported MPCs and the MPE. Lastly, I adjust for a 2014 price level.

**J Additional Model Fit**

Figures 6 - A.11 display the corresponding data and simulated moments for additional target moments, including the remaining four birth cohorts.

![Figure A.6: Model Fit - Mobility (Initial Owners, ELSA Data & Simulations)](image)

(a) Frequency of moves in the last 2 years  
(b) Homeownership rates by Cohort

Figure A.6: Model Fit - Mobility (Initial Owners, ELSA Data & Simulations)


Figure A.6 highlights that the model replicates moving house and tenure decisions. The left panel shows the model captures the infrequent decision to move house, en-
dogenously generating illiquidity in housing. Similarly, the right panel shows the model is able to broadly capture the observed rates of homeownership. If anything, it slightly understates the increase in transitions to renting occurring with age.

Figure A.7: Model Fit - Bequest Probabilities (ELSA Data & Simulations)


Figure A.7 shows the model dispersion in expected bequests matches the data. The left panel shows that for initial owners it varies with age, PI and cohort - capturing salient heterogeneity in the data. Comparing to the right panel shows that the model captures large differences in expected bequests by initial housing tenure.

Figure A.8: Model Fit - Liquid Wealth (Initial Renters, ELSA Data & Simulations)

Figure A.8 shows the model replicates the limited liquid wealth holdings and lack of wealth accumulation for initial renters. The right panel shows the same simulated and data moments for the additional birth cohorts presented in Appendix B. Figures A.9-A.11 produce simulated and data moments for these additional cohorts, showing the model’s ability to match key patterns and heterogeneity extends to these additional cohorts.

Figure A.9: Model Fit - Wealth (Initial Owners, ELSA Data & Simulations)

Figure A.10: Model Fit - Mobility (Initial Owners, ELSA Data & Simulations)
Figure A.11: Model Fit - Bequest Probabilities (ELSA Data & Simulations)


References


K Supplemental Materials (not for publication): Numerical Procedure

This appendix discusses the implementation of each of these procedures in more detail. I solve the model using backwards induction. At each age I compute the optimal savings, housing and consumption decision for all possible combinations of the state variables. I use the policy functions to compute the value function and iterate backwards.

Discretization The model has four discrete state variables: age, health status, family structure and idiosyncratic bequest motive. There are four additional state variables that must be discretized: PI, housing, cash-on-hand, and the aggregate house price level as well as the additional transitory medical expense shock. PI is placed on an unequally spaced grid with 6 elements, where the grid points are concentrated towards the extremes of the distribution. Discretizeing tax policy is described in Appendix C.

Housing, which is both a state and a choice variable, is discretized\(^1\) using a single point to denote current renters and 14 additional points for homeowners - the first 12 points of this grid are placed at the median of the 12 quantiles of the 2002 housing wealth distribution of my ELSA sample (conditional on being below £1,250,000 which covers over 99% of homeowners in the sample) with two additional points placed at £1,250,000 and £2,500,000.

To avoid spurious discontinuities arising from this approximation choice I use a finer grid to simulate the Regression Discontinuity results reported in Table 6. I use 31 possible housing choices and increase the number of points in the region of the tax discontinuity.

Cash-on-hand is placed on a grid with 82 points placed on an exponential scale. I use a small number of cash-on-hand points for the available resource because the solution method (described below) involves calculating an exact solution to the Euler Equation at each point. The log of the aggregate house price level is placed on a grid with 8 elements and the transitory component of medical expenses is placed on a grid

\(^1\)Numerous notches in the transaction tax mean that the budget set is non-convex. This necessitates the practical choice to discretize both state variable and housing choice.
with 3 elements.\textsuperscript{2} Both use the method of Tauchen (1986).

Consumption and next period liquid wealth are not placed on a grid. Instead, individuals can choose any feasible level of consumption and next period liquid wealth. In total, the value function and policy functions are calculated for 3,542,400 combinations of state variables for each age and policy regime.

**Computing the Solution to the Household’s Problem** In order to tractably solve this problem while maintaining a high level of accuracy I model the choice of housing as a discrete choice and follow the modified version of the endogenous grid-point method (EGM) algorithm for discrete continuous dynamic choice models in Iskhakov et al. (2017).\textsuperscript{3} This variation on the EGM algorithm (Carroll, 2006) uses discrete choice (housing) conditional euler equations to find conditional consumption and savings policies.

The continuation value of the model studied in this paper is not globally concave due to the presence of the consumption floor and the discrete housing decision which introduce kinks in the value function.\textsuperscript{4} Consequently, the optimal policies delivered by the EGM step do not necessarily correspond to the optimal policies of the model. In order to ensure that the globally optimum consumption value is selected from the multiple solutions to the Euler Equation, due to the presence of nonconvexities, I construct the (housing choice specific) upper envelope over segments of the (housing choice specific) value function in regions of the endogenous cash-on-hand grid where multiple solutions are detected. This procedure follows the method described in Iskhakov et al. (2017). For saving below the consumption floor, the marginal utility of saving is 0 and I follow Hubbard et al. (1995) in replacing the consumption floor with an indicator function in the Euler equation.

Unconditional policy and value functions are recovered by taking the maximum over each discrete choice. In this paper, cash-on-hand is not deterministic and I adapt their method by controlling for household savings (the deterministic component of cash-on-hand) as the end of period state variable.

The DC-EGM method specifies a grid for the post-decision savings state and

\textsuperscript{2} Results with 3 or 5 points for the transitory shock are indistinguishable
\textsuperscript{3} Fella (2014) also proposes an EGM algorithm for non-smooth non-convex problems
\textsuperscript{4} Typically kinks which occur due to next period non-concavities are referred to as primary kinks while kinks that perpetuate backwards from future period non-concavities are referred to as secondary kinks. The presence of further uncertainty in future periods helps to smooth out some of the secondary kinks, but the approach used here accounts for both types of kinks.
returns the housing choice-specific optimal policies and value functions on an endogenous grid. Consequently, an extra step is needed before it is possible to compare the payoff associated with different housing choices for at initial cash-on-hand - the upper envelope calculation. I refer to this step as *regularization* and interpolate each of the housing choice-specific value functions and policy functions onto a pre-specified exogenous cash-on-hand grid that is common across housing choices. In the *regularization* step, when interpolating the value function for households who choose to locate at the borrowing constraint for the next period I use the analytic solution for their value function (given the computed expected value function associated with the borrowing constraint) next period.

**Optimal Policy in Simulation** Simulated households do not have to live on the discrete points of the cash-on-hand space where housing choices are determined. Consequently, in the simulations I compute optimal choices assessing each housing choice and allowing simulated households to consume equally spaced proportions of their cash-on-hand (after housing adjustment) on a 501 point grid.

**Minimising the GMM Criterion** The GMM criterion function may have multiple local minima. SMM estimates are typically found by employing multi-start derivative free algorithms. I proceed in two steps.

First, I evaluate the objective function at 3,000 candidate parameter vectors drawn from a 14-dimensional (the number of parameters to be estimated) Sobol sequence. I rank the vectors by the value of the objective and use the top 1% candidate parameter vectors to generate a new hypercube on the parameter space. I take the minimum and maximum parameter value in each dimension to produce the smallest hypercube surrounding the polytope defined by the convex hull of the highest ranked candidate parameter vectors. This greatly reduces the overall admissible parameter space without necessarily producing tight bounds on any individual parameter. I iterate on this procedure 5 times. Sampling points from the hypercube slows the rate at which regions of the parameter space are discarded, trading off the gain from reducing the parameter space against eliminating potentially profitable search regions too quickly. This is similar to the averaging of the best estimate and new draws from a Sobol sequence in the Tik-Tak algorithm described in Arnouldy et al. (2019). I iterate this step 5 times. The second stage samples from the new hypercube to generate starting
values for the BOBYQA algorithm (Powell, 2009), a trust region based numerical optimizer. Typically, BOBYQA uses fewer evaluations of the objective function than other derivative free methods (for example the Nelder-Mead Simplex method Nelder and Mead, 1965). By combining the BOBYQA method with the multiple starting points selected above it appears that the parameters obtain the global minimum.

At each stage of the estimation I parallelize both the calculation of the dynamic programming problem and simulation and the initial candidate parameter vector using the facilities of the University College London Computer Science High Performance Computing Cluster.

**Computing Standard Errors**  I calculate the Jacobian of the moment conditions with respect to the parameters by numerical differentiation with a five point stencil in each dimension (central differencing).

**References**


