Article

Wealth and Consumption in the UK: A Two-Asset Heterogeneous Agent Model

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Abstract
Analysing the sensitivity of the income and wealth distribution to changes in taxes and government transfers is of particular importance in the current environment of high inflation and low growth. In this paper, evaluate the effect of discretionary fiscal policy on the joint distribution through calibration of a two-asset heterogeneous agent model with uninsurable idiosyncratic income risk and no aggregate uncertainty to the UK income and wealth distribution. I accomplish this using data on household balance sheets from the Office for National Statistics' Wealth and Assets Survey (WAS). My contribution to the literature on distribution-realistic general equilibrium models may be useful in informing the debate on the efficacy of unconventional fiscal and monetary policies on inequality in the UK.

Keywords: Macroeconomics, Heterogeneous, Theory, Inequality

1. Introduction

Given the increasing focus on inequality over the past decade and advances in computing capacity that have given rise to complex macroeconomic modelling, there is a fast-growing literature researching the effects of heterogeneity on the effectiveness and implications of monetary and fiscal policy. This burgeoning literature tends to focus on calibrations to US households. I contribute to the existing literature by calibrating a two-asset model of household heterogeneity to data on UK households' balance sheets using the Wealth and Assets Survey (henceforth WAS) collected by the Office for National Statistics.

It is difficult to overstate the crucial importance of understanding the quantitative theoretical model underlying empirical analyses of marginal propensities to consume. One-asset theoretical models that are calibrated to match realistic wealth distributions imply a small fraction of the population are constrained. Hence the effect of the constrained households higher MPCs is negligible with regards to aggregate responses of macroeconomic outcomes.

I use a two-asset heterogeneous agent model to analyse the effect of fiscal policy on income and wealth inequality within a UK context. The primary contribution of heterogeneous agent models is the incorporation of uninsurable income risk and an occasionally binding borrowing constraint that violates Ricardian equivalence. This results in inefficient equilibria and thus generates the potential for significant real effects on aggregate variables of fiscal policy interventions. Assuming households exhibit prudence, the introduction of uninsurable idiosyncratic income risk and an occasionally binding borrowing constraint induces a precautionary saving motive in order to self-insure against consumption volatility, in addition to classical intertemporal substitution. The model I use includes one further extension to earlier Bewley-Huggett-Aiyagari-type models in the form of a binary distinction between the types of assets owned by households, namely liquid and illiquid. The return on the illiquid asset is always higher than the return on the liquid asset but withdrawing funds from the illiquid asset incurs a transaction cost thus creating an inherent trade-off between keeping sufficient liquid assets at hand to smooth idiosyncratic income shocks and benefiting from the higher return of the illiquid asset.

This categorisation of assets by liquidity introduces a crucial new feature to the model in terms of household behaviour. In this model, there are broadly three types of households: those that have low liquid and illiquid wealth with high MPCs, and those that have high liquid and illiquid wealth with low MPCs but most interestingly there are now also households with low liquid but high illiquid wealth who exhibit high MPCs despite their net worth being comparable to the low MPC households. These households rationally choose not to smooth income shocks due to the frequent transaction costs involved in using illiquid assets to smooth or the opportunity cost of large liquid asset holdings, which earn a lower rate of return than illiquid assets.

It is therefore apparent that the higher MPCs of these households, henceforth referred to as 'wealthy Hand-to-Mouth (HtM)' households, is sensitive to the magnitude of the return differential between liquid and illiquid assets and the size of transaction costs. If, for example, a large fiscal stimulus is received then wealthy HtM households may optimally choose to pay a sufficiently small transaction cost, or any transaction cost with sufficiently large return differential between assets, in which case their consumption-saving behaviour more closely matches that of the non-HtM Ricardian households.

	Illiquid Wealth	**Liquid Wealth**	**MPC**
Poor HtM	Low	Low	High
Wealthy HtM	High	Low	High
Non-HtM	High	High	Low

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The large differences in measured effectiveness of fiscal and monetary policy between countries may be explained in large part by the difference in the share of HtM households, which depends on heterogeneous factors such as domestic retail banks' willingness to lend, the national interest rate and the degree to which property is used as a long-term investment. For example, Guo et al (2022) compare 20 European countries and find empirical evidence that the higher the fraction of poor HtM households, the greater the fiscal spending multiplier and the higher the fraction of wealthy HtM households, the greater the fiscal tax multiplier. This is because wealthy HtM households are wealthier and therefore spend more on consumption despite their limited liquidity. Therefore, a reduction in taxes for example will generate a stronger consumption response among wealthy HtM households since they are more willing to overcome their liquidity constraint. Furthermore, the relative impact of a tax cut is likely to be higher on wealthier households, who are more likely to be subject to higher tax brackets. On the other hand, spending multipliers are more sensitive to the behaviour of poor HtM households since fiscal transfers tend to redistribute income from wealthy households to poorer ones irrespective of liquidity constraints, resulting in stronger consumption responses to changes in government spending by poor HtM households.

This paper will focus on the analysis of changes in return differentials and transaction costs on the stationary distributions of income and wealth among UK households, and hence provide a discussion of the implications of liquidity constraints for monetary and fiscal policy.

The remainder of this paper is organised as follows: Section 2 reviews the recent literature on heterogeneous agent models, Section 3 presents and summarises the data on the distributions of income and wealth and the share of HtM households, Section 4 describes the model in detail including a discussion of the calibration of the model to the data, Section 5 discusses the results of the model and implications for policymakers, and Section 6 concludes.

2. Literature Review

In the classic heterogeneous agent literature, households receive idiosyncratic productivity shocks against which risk-averse households would optimally choose to insure against due to the loss of income but are unable to due to capital market imperfections. This is the approach followed by Bewley (199X), Huggett (1993), and Aiyagari (1994). In the absence of complete capital markets, households instead self-insure by accumulating precautionary savings in the form of a liquid asset when income is high that can be later dissaved during periods of low income thereby reducing the sensitivity of consumption to changes in income. There is also a zero borrowing constraint such that households can only accumulate positive holdings of the liquid asset, i.e. no borrowing is allowed. This model setup results endogenously in a heterogeneous distribution of wealth due to the differences in the paths of productivity shocks among households. There is no aggregate uncertainty in my model, only idiosyncratic risk such that the distribution of income and wealth will be dependent only on the fraction of HtM households, who exhibit high MPCs, and therefore sensitive to changes in the liquidity return profile and transaction costs.

Heterogeneous agent models are often calibrated to microeconomic datasets according to a subset of moments e.g. growth rate, autocorrelation, (Krusell & Smith, 1998). However, this tends to result in unrealistically low inequality of income and wealth due to truncation and underreporting of the highest incomes and wealth. Several authors have attempted to replicate a more realistic distribution by directly modelling it as a Power-law distribution e.g. Kaymak & Poschke (2016) and Castañeda et al. (2003). However, it is possible to generate realistic distributions of income and wealth in two-asset heterogeneous agent model without the need for ad hoc distributional assumptions.

Single-asset heterogeneous agent models tend to endogenise the fraction of HtM households by use of a simple borrowing constraint, see Aiyagari (1994) and Krussell & Smith (1998). However, standard calibrations of this type of model fail to replicate the share of high-MPC households recorded in empirical studies. Some authors attempt to correct for this issue by calibrating the model to liquid wealth only. This tends to better match the consumption behaviour of households but fails on another count by omitting a large part of the wealth distribution and at the same time significantly understating the total aggregate wealth.

10.14324/111.444.2755-0877.1889

In their paper titled Monetary Policy according to HANK, Kaplan, Moll, & Violante outlines a similar two-asset heterogeneous agent model but with the addition of price and wage rigidities on the production side in the New Keynesian tradition. This more complex model matches well the income and wealth distribution of the United States as well as microeconomic data on the MPCs of households across the distribution. This paper highlights the crucial effect of wealthy HtM households on macroeconomic variables. They find that the direct effect of monetary policy, operating through the classical intertemporal substitution effect, account for just one fifth of the total effect on aggregate variables. The remaining four fifths comprise indirect effects on non-Ricardian households induced by higher labour demand and therefore wages, as well as smaller secondary effects from households rebalancing their portfolios between liquid and illiquid assets, and the effect of higher tax revenues on government transfers. Importantly, the aggregate consumption response to conventional monetary policy is now dependent on shock persistence due to the presence of non-Ricardian households who cannot respond sufficiently to the policy shock contemporaneously. The two types of HtM households both exhibit high MPCs but for different reasons; poor HtM households are budget-constrained whilst wealthy HtM households are credit-constrained.

(Galí et al., 2007; Bilbiie et al., 2008; Oh and Reis, 2012; Kaplan and Violante, 2014; Farhi and Werning, 2016) all indicate that a greater proportion of liquidity constrained households increases the consumption response to government policy. When Ricardian equivalence does not hold, fiscal policy can effectively replicate monetary policy outcomes. This has significant implications for the optimal policy response when monetary policy is constrained by the effective lower bound.

Heathcote (2003) finds that the aggregate effects depend on impact on non-Ricardian households as they have large consumption responses to transitory income shocks, such as those generate by discretionary fiscal policy. Tax cuts have real effects through capital and labour markets. Constrained households prefer to spend not save so investment muted. Evidence suggests debt-financed spending has a multiplier of 0.2-0.5, orders of magnitude larger than the c.0.04 predicted by RE. RE fails if taxes are distortionary, households are credit constrained, intergenerational externalities, or if households are myopic. Consumption responded most to the tax distortion rather than the credit constraint.

Empirical data suggests that wealthy households, whose income is mainly derived from returns on assets, have lower marginal propensities to consume (MPCs) out of a permanent change in income than poor households, whose income is mostly earned through provision of labour. In particular, higher liquid wealth is associated with significantly lower MPCs; households with high liquid wealth have MPCs close to 1, whereas households with low or no liquid wealth have MPCs close to 0 (Carroll et al, 2017). This implies that Ricardian equivalence may in fact hold for those households with high liquid wealth, regardless of illiquid wealth holdings, whilst at the same time being violated by constrained households with insufficient liquid wealth to smooth consumption in response to temporary changes in income. Therefore, the aggregate effect of temporary income changes, such as those from fiscal stimulus, may depend less on the fraction of poor households and more on the fraction of households that exhibit HtM behaviour, thus including households with high illiquid wealth but either permanently or temporarily low liquid wealth.

Wealthy households, for example, may own their own home without a mortgage and have a large pension portfolio such that an increase in interest rates may benefit them by increasing the rate of return on their pension through higher bond yields. Poor households will be affected in the opposite direction since they tend to have very low levels of property and pension wealth combined with significant debts such that a rise in interest rates would increase the interest repayments on their debts and increase their rent as mortgaged landlords pass on their higher interest repayments. However, wealthy HtM households are likely to be mortgaged homeowners for whom an increase in interest rates would directly increase their monthly mortgage repayments so whilst their savings and pension portfolios may benefit from higher interest, in the short term their disposable income falls.

Ricardian equivalence states that changes in the timing of taxes, with the same present value of tax revenue, will not affect consumption since households' consumption behaviour is only dependent on lifetime income. This result relies on the conditions that markets are complete, and that the government can implement lump-sum taxes and transfers. Many studies have suggested that Ricardian equivalence fails to hold in general, most clearly because

taxes tend to be proportional, such as income and sales taxes, but also due to market imperfections created by an occasionally binding borrowing constraint. As such, risk-averse households hit by a negative income shock would like to smooth consumption by borrowing to fund consumption in the current period to be repaid at the expense of consumption in future periods. However, when the borrowing constraint binds then the best response is to consume their entire income. Hence, already constrained households, such as HtM households, will respond to tax changes, in violation of Ricardian equivalence.

3. Data

Data for the household balance sheets comes from the Office for National Statistics' biennial Wealth and Assets Survey (WAS). The WAS started in 2006 and provides the most comprehensive longitudinal data on UK household wealth, decomposed by asset type and household characteristics. The latest round of the survey comprised approximately 18,000 household interviews. The household level data is collected from one reference person, usually the head of the household, this includes data on household demographics, assets, and liabilities. Whereas the person level data is collected individually for each person aged 16 or older within each household, which includes more detailed personal questions regarding economic status, level of education, employment status, receipt of benefits, and value of financial and non-financial assets.

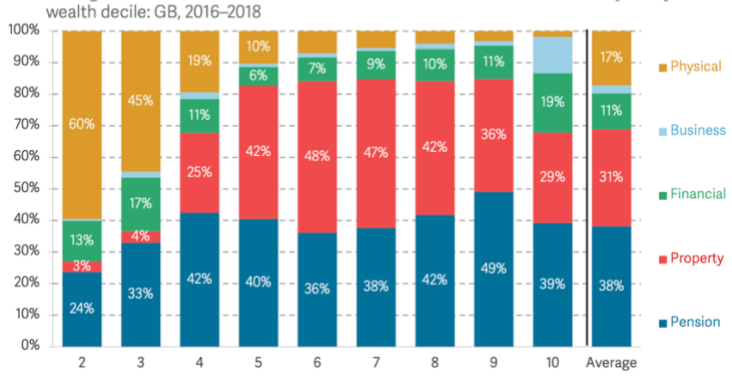
The ONS account for the under-sampling of the highest income and wealth households by oversampling the top decile according to data on financial wealth collected by HMRC. Households with financial wealth above the set threshold were 2.5x more likely to be sampled than households below the threshold. However, despite being statistically oversampled, high net worth households, are far less likely to respond to wealth surveys due to time constraints and privacy concerns.

Additionally, unlike other household financial surveys, such as the US Survey of Consumer Finances, the WAS does not exclude defined benefit pension wealth. The ONS estimates the value of defined benefit pensions and annuities using expected or received retirement income with external economic indicators such as annuity rates and discount factors.

However, the WAS survey is nonetheless most likely underestimating the wealth of the richest households. In particular, despite collecting data on private business wealth, which comprises a larger share of wealth for the very richest households (see figure below), it is not included as a component of aggregate household wealth. Once the data is adjusted to account for business wealth (c.5% of the current estimate), underreported data on the wealthiest households from other sources, and a Pareto correction, total aggerate household wealth in the UK is 8% higher than reported by the ONS, at around £16.4tn. The distribution of wealth is also less equal following the aforementioned statistical adjustments with the top decile's share of total wealth 4 percentage points higher (Advani, et al 2021).

FIGURE 4: **Business assets are much more prevalent at the top of the wealth distribution**

Average share of total net wealth contributed from different asset classes by family net wealth decile: GB, 2016–2018



Notes: The lowest decile is excluded as net wealth is negative. Source: Advani, Bangham and Leslie (2021).

10.14324/111.444.2755-0877.1889

The four largest components of wealth, private pension, property, financial and physical, are defined as follows.
Private pension wealth - The value of any pension pots already accrued that are not state basic retirement or state earning related. This includes occupational pensions, personal pensions, retained rights in previous pensions and pensions in payment. Estimating the value of some private pension pots is straightforward. For example, if a pension is a defined contribution type scheme (not in payment) the valuation is obtained from the respondents' latest statement from their pension administrator. This is an accurate estimation of each individual pension pot taking into account any relevant market influences (for example, investment returns).

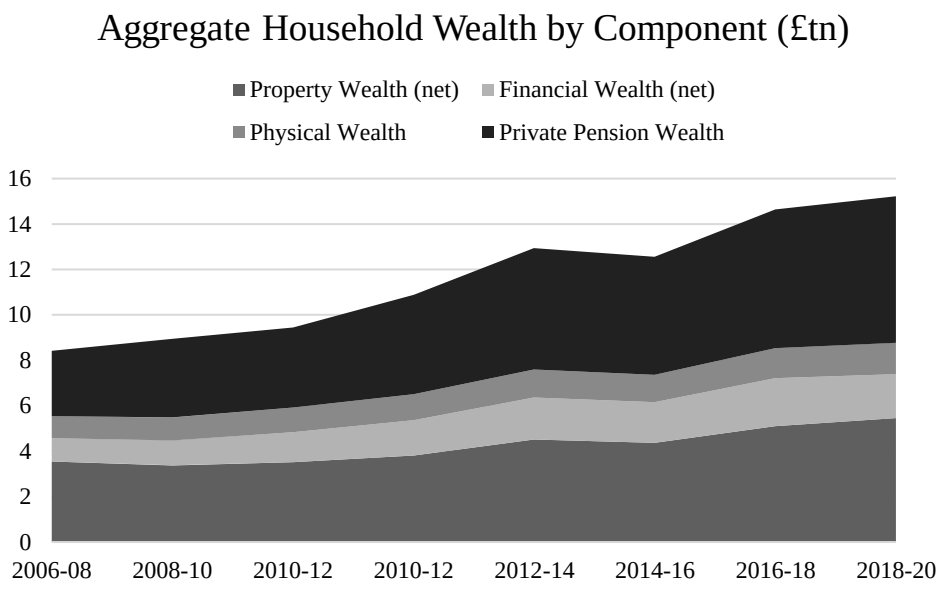
Property wealth (net) - Respondents' self-valuation of any property owned, both their main residence plus any other land or property owned in the UK or abroad, less the outstanding value of any loans or mortgages secured on these properties. Self-valuation tends to yield higher estimates of worth than most other property indicators may suggest – however, when assessing individuals' opinions or behaviours, it is this perceived worth that will drive the individuals concerned.

Financial wealth - The values of any financial assets held, both formal investments such as bank or building society current or saving accounts, investment vehicles such as Individual Savings Accounts (ISAs), endowments, stocks and shares, and informal savings (money under the bed or loaned to family or friends) and children's assets; less any financial liabilities such as outstanding balances on credit cards, arrears on household bills, loans (including student loans) from formal or informal sources.
Physical wealth - The (self-evaluated) value of household contents, possessions and valuables owned such as antiques, artworks, collections and any vehicles.

In the most recent 2018-20 survey, total net wealth was estimated at £15.2 trillion, more than 6.5 times the total annual income (GDP) of around £2.2 trillion in 2019. Total aggregate wealth has increased in real terms by approximately 5% per annum since the first survey wave in 2008. This had largely been driven by population growth and ageing, as well as relatively high rates of return on the largest components of household wealth, namely housing equity and private pension wealth. Net property wealth has benefitted from sustained increases in house prices over the period combined with an increasing share of unmortgaged homeowners. Similarly, pension wealth has grown due to demographic factors such as the ageing population as well as an increase in pension scheme membership by auto-enrolment.

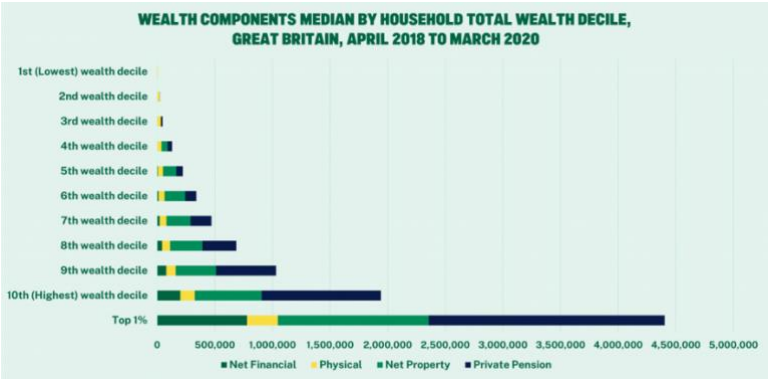
On the other hand, there has been little growth in physical wealth, although it is the smallest component of wealth for most households and contributes a negligible proportion of total aggregate wealth. Conversely, net financial wealth, the second smallest component, has grown the fastest over the period from £1tn in 2008 to nearly £2tn in 2020, however its relatively minor contribution to total aggregate wealth means it only contributed 2 percentage points to the overall increase in wealth. Important to note is that whilst physical wealth is relatively equally distributed, net financial wealth is not with the poorest households in net financial debt, the median household owning just modest savings wealth, and the wealthiest households owning substantial shareholdings and other financial investments.

10.14324/111.444.2755-0877.1889



The proportion of total household wealth held in private pensions has increased every year since the start of the survey and now comprises the single largest component of total wealth at 42%, overtaking property wealth which now makes up 36%. This means that nearly 80% of total household wealth is held in either pensions or property with financial and physical wealth contributing just 13% and 9% respectively. Despite their relatively minor contributions to total wealth, financial and physical wealth are by far the most unequally distributed. The most recent survey data shows that top 1% of the wealth distribution in the UK directly owns more financial assets than the bottom 80% of the distribution combined, with more than 50% of the population directly owning no financial assets at all. Furthermore, close to half the population own more financial debt than financial assets.

Although not as unequal as financial assets, the distributions of pension, property, and physical wealth are nonetheless skewed. For instance, the top decile of the wealth distribution owns 43% of total wealth, including 64% of private pension wealth, compared to the bottom half of the distribution who own just 9%. It is interesting to note that the top 10% of households by wealth owns 290 times more in total assets than the bottom 10% by wealth but the richest 10% of households by income earns just 6.8 time more than the bottom 10% by income. Also, the share of earned and unearned income going to the top 1% of richest households has nearly tripled in the past four decades, from 3% in the late 1970s to about 8% today (IFS).
The top 1% of households by wealth, those with household wealth over £3.6m, the largest component of wealth, by a large margin, was pension wealth with a median value of £2m. Meanwhile, the poorest decile, those with household wealth of less than £15,400, owned mainly physical assets with more than half owning no property, pension, or financial assets at all.



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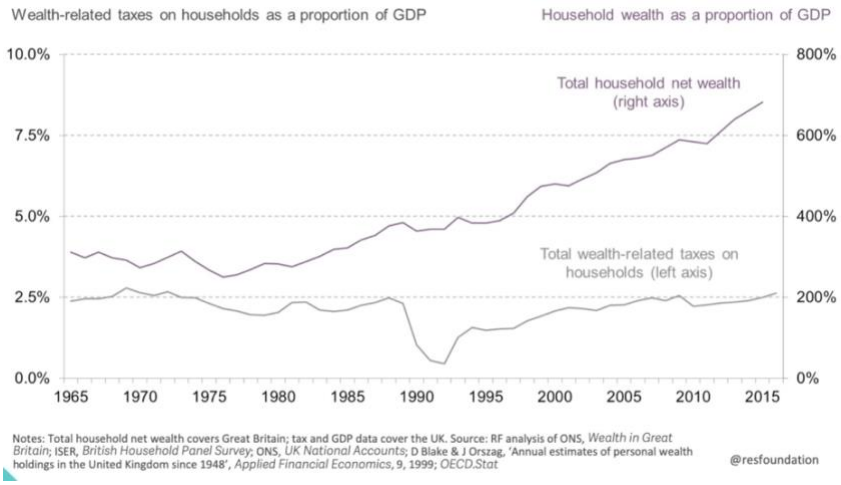
In determining the fraction of poor HtM, wealthy HtM, and non-HtM, I follow the categorisation of Kaplan & Violante (2014a). Income is defined as net employment or self-employment earnings and benefits e.g. Job Seeker's Allowance. I drop households with heads less than 20 or more than 79 years old. Consistent with the literature, I define illiquid wealth is defined as the combined value of the main residence, other houses, land net of mortgages, occupational and personal pensions, insurance products and annuities, and National Savings products, as reported in the survey. Conversely, liquid assets are defined as current and savings accounts, Individual Savings Accounts (ISAs), and holdings of shares, corporate bonds, and government bonds.



Kaplan, Violante & Weidner (2014), using 2010 data, find that the median household balance sheet is comprised of a small holding of liquid wealth, primarily current and savings accounts, and larger holdings of illiquid wealth, mainly housing equity and pensions. Note that they find the median household owns no financial assets. They identify HtM households as those who consume all their after-tax income in each pay period then differentiate between poor- and wealthy HtM according to household net wealth. For the UK, they find that the median net total wealth of £187,157 was 6 times the median income of £29,340 in 2010. They therefore conclude that 33.5% of UK households are HtM, comprising 23.2% wealthy-HtM and 10.3% poor-HtM.

In the most recent survey, median net wealth was £302,500, comprising mostly property wealth, compared to median net income of just £29,600 (in 2019), which is more than 10x, significantly higher than the OECD average. Following the methodology of Kaplan, Violante & Weidner (2014), using the most recent data (from 2018-20) I estimate that 38.7% of UK households are HtM, comprising 27.1% wealthy-HtM and 11.6% poor-HtM. This represents an increase of 3.9 and 1.3 percentage points respectively, indicating a slight increase in the fraction of households with low total wealth but a much greater increase in the fraction of households with low liquid wealth but high illiquid wealth.

This may be explained in part by the falling real incomes and rising housing costs for poorest households who have been forced to dissave or increase borrowing to maintain the same level of consumption. Despite the introduction of occupational pension auto-enrolment in 2012, the increase in the number of employees saving into pensions, the primary effect has been to increase the proportion of employees making very low contributions. Furthermore, the increase in self-employment and gig-work has reduced the number of working people eligible for occupational pensions to just two-thirds in 2017 (IFS, 2018). Alternatively, employees facing higher minimum contributions may simply be offsetting this by reducing their contributions to savings accounts or debt repayments, both liquid forms of wealth. It should be noted that measures of inequality that look only at net income, as opposed to effective disposable income, are likely to underestimate the degree of inequality in standard of living between households. For example, if a household is spending 30-50% of post-tax income on housing costs as estimated in recent years due to increases in rent and energy costs, then this represents a significant transfer of money from the poorest households with no property wealth to the wealthiest households; the wealthiest 20% own 60% of all property wealth (ONS).

Conversely, the continuing increase in house prices has led many households to use much of their liquid wealth as a deposit for a mortgage on a house in order to benefit from the higher returns and lower costs of home ownership. Additionally, research by the Institute for Fiscal Studies indicates that around 31% of working age adults believe the state pension will not exist in 30 years' time and more than half expect to have a lower real disposable income in retirement than their parents. As such, households are optimally deciding to increase their illiquid wealth through higher pension contributions, private pension contributions for example have increased from 8% in 2010 to 16.6% in 2019 (DWP, 2020). This may also be the effect of the stepping up of legal minimum employee contributions from 1% to 5%.

3. Model

I describe a simplified discrete time version of the model of the consumption-saving problem used in the quantitative simulations below. Consider a household that lives for 3 periods, t = 0, 1, 2, but cannot consume in period 0. It is assumed that the consumption preferences are represented by a strongly separable utility function of the following general form:

$$\begin{aligned}
&\max\ u(c_t)\ \ subject\ to\\
&\Delta b_t = (1-\zeta)wz_t + r_b b_t - d_t - \chi_t - c_t,\\
&\Delta a_t = r_a a_t + \zeta w z_t + d_t\\
&a_t \geq 0, b_t \geq \underline{b}\\
&t = 0, 1, 2
\end{aligned}$$

The Bellman equation representation of the household's consumption-saving problem is therefore:

$$\rho V(a,b,z) = \max u(c) + V_b(a,b,z)\Delta b_t + V_a(a,b,z)\Delta a_t + \sum_{z'} \lambda(z,z')\big(V(a,b,z') - V(a,b,z)\big)$$

Solving for the first order conditions gives:

$$u'(c) = V_b(a,b,z)$$

$$V_b(a,b,z)\big(1 + \chi_d(d,a)\big) = V_a(a,b,z)$$

Given that $\chi_d(d,a) = \chi_0 + \chi_1\left(\frac{d}{a}\right)$ if $d > 0$ and $\chi_d(d,a) = -\chi_0 + \chi_1\left(\frac{d}{a}\right)$ if , $d < 0$ then conditional on paying the fixed cost, optimal deposits are given by:

$$d = \max\left(\frac{V_a}{V_b} - 1 + \chi_0, 0\right)\left(\frac{a}{\chi_1}\right) + \max\left(\frac{V_a}{V_b} - 1 - \chi_0, 0\right)\left(\frac{a}{\chi_1}\right)$$

The interpretation of this theoretical result is thus that the optimal consumption-savings rule for the household is to deposit into the illiquid asset only when the ratio of the marginal value of illiquid wealth to liquid wealth is relatively large. The shape of the transaction cost function drives the behaviour that households will optimally choose inaction when the ratio of the marginal values of wealth is near unity.

Here a_t denotes illiquid assets, b_t liquid assets, c_t consumption, z_t idiosyncratic productivity, d_t deposits into the illiquid asset, and χ_t the transaction cost. The wage is denoted by w, the return on illiquid assets is r_a and the return on liquid assets is r_b. In addition, a constant fraction, ζ, of income is automatically deposited in the illiquid account at the start of each period, representing automatic employee pension contributions.

For simplicity, assume that the utility function exhibits constant elasticity of substitution. Also assume that initial household wealth is normalised to 1 such that the savings decision in period 1 may be interpreted as the fraction of wealth invested in each asset type. Also let $z_t \in (z_L, z_H)$ such that there are two productivity, and therefore income, states that are assigned according to a Poisson distribution.

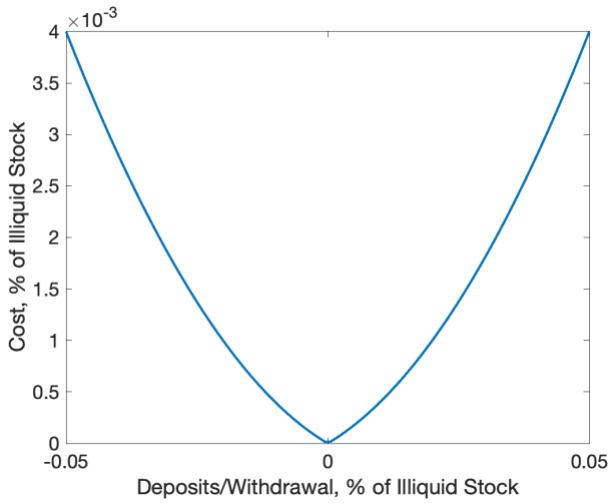
10.14324/111.444.2755-0877.1889

This setup makes it possible to classify households into HtM and non-HtM according to their consumption decision in period 1. In particular, if a household holds a positive amount of liquid and illiquid wealth at the end of period 1 then they are considered non-HtM. If the household holds no liquid or illiquid wealth, then they are considered poor HtM but if they have some non-zero holding of liquid wealth then they are classified as wealthy HtM as described above.

I calibrate this partial equilibrium model to the UK economy using the method of Kaplan et al (2014) by setting the deep parameters to generate a ratio of median wealth to median income equal to the data from the WAS. This is analogous to the approximate aggregation method of Krussell & Smith (1998) whereby using only one moment, namely the mean of the distribution, is sufficient to achieving accurate distribution forecasts and therefore a reasonable match to the joint distribution.

I utilise this calibrated model to show the effect of changes in the return differential between liquid and illiquid wealth on the stationary distribution of wealth. This may have implications for fiscal policy with regard to optimal capital taxation but also highlights the relative importance of wealth inequality in determining the level of income inequality. In addition, I explore the robustness of my results to changes in the parameterisation of the model, in particular to changes in deep parameters, including the coefficient of risk aversion, and subjective discount rate.

My calibration is relatively straightforward; for the standard parameters I use γ = 2, ρ = 0.05, r_a = 0.05, r_b = 0.03 (0.12 if negative liquid wealth), χ_0 = 0.03 χ_1 = 2. Although there are a range of values for γ used in the literature, largely due to the significant heterogeneity within households, I choose 2, implying an elasticity of intertemporal substitution of approximately 0.47. The calibration of ρ is such that the ratio of median total wealth to median annual income is 10.30 for the low types and 8.49 for the high type, which match the empirical estimates of around 10.



The transaction cost function of the form already described has the above graphical representation in the quantitative model. The transaction cost function is kinked at $d = 0$ implying inaction on the part of households whilst the convexity of the curve implies finite deposit rates to ensure households do not accumulate an infinite amount of illiquid wealth.

4. Results

In the baseline specification, whereby the model is calibrated to match the median household wealth to median net income of approximately in the data, the distributions of consumption, wealth, liquid savings, illiquid savings, and deposits are shown below.

Percentile	10%	20%	30%	40%	50%	60%	70%	80%	90%
Consumption (Low Type)	4.9422	5.5857	6.0427	6.4205	6.7901	7.1956	7.6306	8.1191	8.6882
Consumption (High Type)	5.2191	5.8139	6.2464	6.6192	6.9945	7.3948	7.8252	8.2935	8.8458
Deposits (Low Type)	-2.4886	-1.4262	-0.8085	-0.3521	0	0	0	0.1159	0.4495
Deposits (High Type)	-2.0081	-1.1028	-0.5562	-0.1506	0	0	0	0.1987	0.5216
Savings (Low Type)	-4.4169	-4.07	-3.7377	-3.3983	-3.0434	-2.6647	-2.2536	-1.742	-0.7502
Savings (High Type)	-2.8465	-2.5125	-2.1952	-1.8692	-1.5273	-1.1739	-0.7884	-0.3515	0.2932
Illiquid Savings (Low Type	0.0994	0.6054	0.9677	1.3156	1.6057	1.8737	2.1054	2.319	2.6019
Illiquid Savings (High Typ	0.5765	1.0087	1.3564	1.6629	1.9454	2.1692	2.3767	2.59	2.872

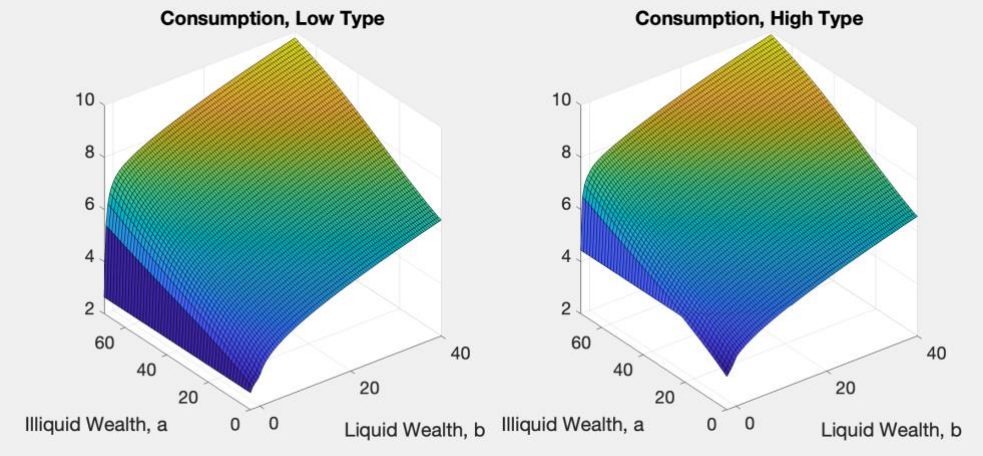


Figure 1: Consumption for Low and High Types

This figure shows the consumption policy functions for agents of the low type (left) and high type (right). Each surface represents the relationship between illiquid wealth and liquid wealth with consumption as the third dimension. The surfaces illustrate how agents adjust their consumption based on their wealth levels. The darker regions represent higher consumption levels.

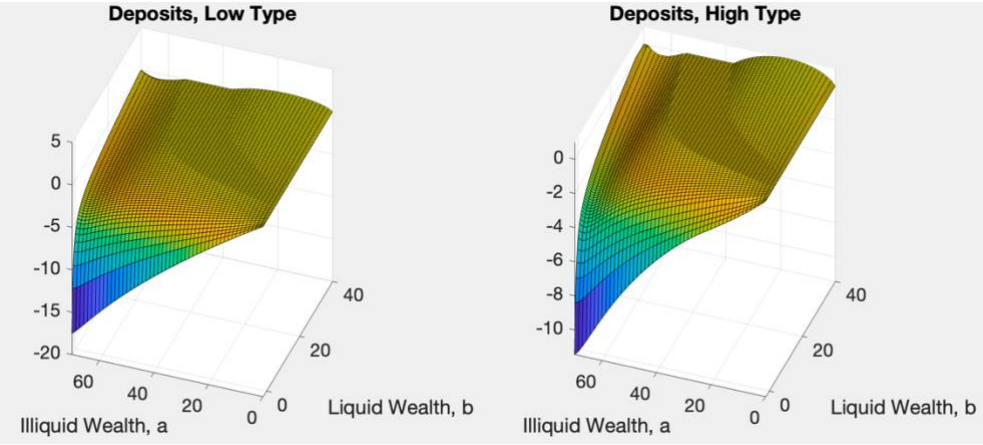


Figure 2: Deposits for Low and High Types

Similar to Figure 1, this figure shows the deposit policy functions for agents of each type. Deposits are plotted against illiquid wealth and liquid wealth. The surfaces illustrate how agents decide to deposit or withdraw funds based on their wealth positions.

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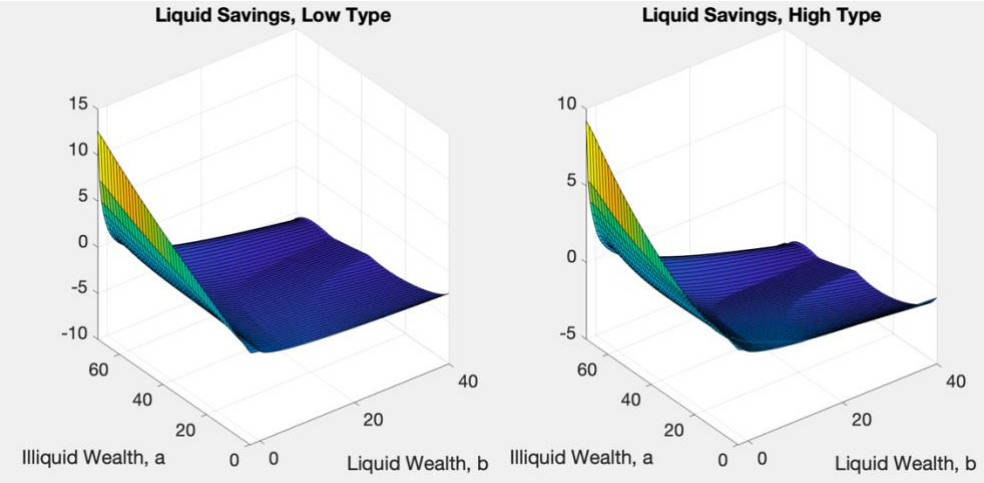

Figure 3: Liquid Savings for Low and High Types

This figure displays the liquid savings policy functions for agents of each type. It shows the amount of liquid wealth an agent holds after considering consumption and deposits/withdrawals. Again, the surfaces illustrate how agents adjust their liquid savings based on their wealth levels. Each point on the plots represents the amount of liquid wealth an agent holds after accounting for consumption and deposits/withdrawals. For example, the peak value for liquid savings of around 10, means that households with the maximum allowable liquid wealth of 70 and minimum liquid wealth of -2, choose to hold approximately 10 units of liquid wealth in response to their current financial situation.

The point of liquid savings of 10 can provide insights into the behaviour of agents. It suggests that, for the given wealth levels, these agents find it optimal to hold a certain amount of liquid wealth for future consumption or potential needs. The point's position on the plot relative to other points gives you an idea of how agents' liquid savings decisions change across different wealth levels and economic circumstances.

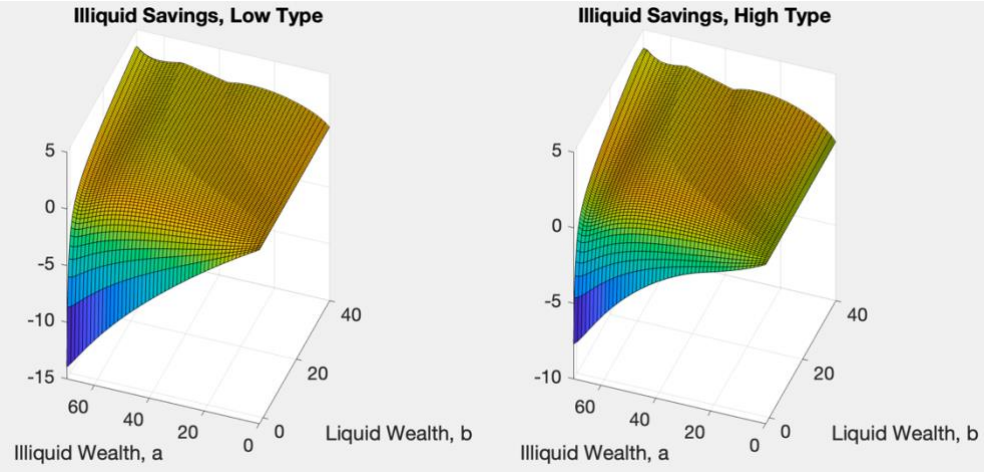

Figure 4: Illiquid Savings for Low and High Types

This figure shows the illiquid savings policy functions for agents of the low type (left) and high type (right). It represents the amount of illiquid wealth an agent retains after adjusting for consumption and deposits/withdrawals. The surfaces illustrate how agents manage their illiquid savings.

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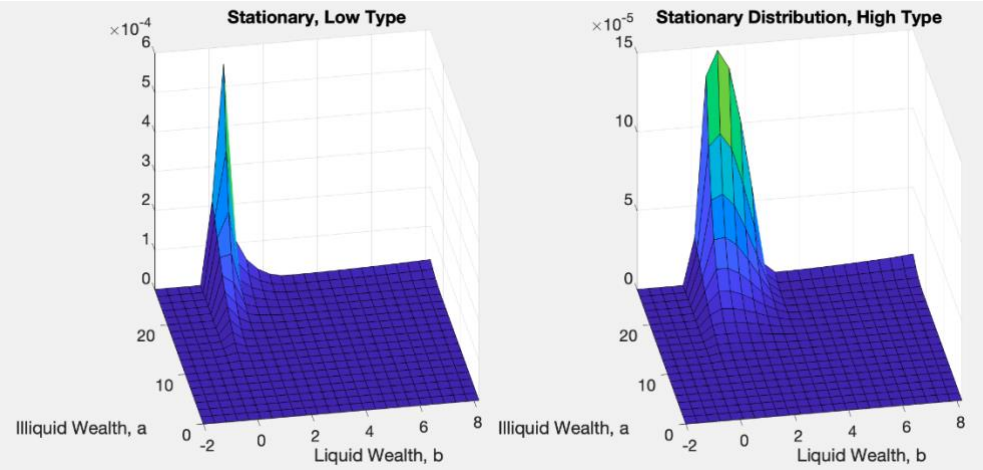

Figure 5: Stationary Distribution for Low and High Types

This figure visualizes the stationary distribution of agents' wealth for the low type (left) and high type (right). Each surface represents the density of agents at different combinations of liquid wealth (b on the x-axis) and illiquid wealth (a on the y-axis). The surfaces indicate the distribution of household total wealth in the economy.

Percentile	10	20	30	40	50	60	70	80	90
Consumption (Low Type)	1.7%	1.4%	0.9%	0.4%	-0.3%	-1.1%	-1.8%	-2.5%	-2.6%
Consumption (High Type)	1.6%	1.2%	0.7%	0.1%	-0.6%	-1.4%	-2.1%	-2.5%	-2.6%
Deposits (Low Type)	32.8%	80.0%	113.6%	214.3%	N/A	N/A	N/A	-100.0%	-100.0%
Deposits (High Type)	58.2%	110.6%	170.8%	518.5%	N/A	N/A	N/A	-100.0%	-100.0%
Savings (Low Type)	-18.8%	-20.6%	-21.7%	-21.7%	-20.4%	-17.9%	-17.1%	-20.0%	-35.4%
Savings (High Type)	-31.0%	-35.7%	-39.6%	-42.9%	-45.4%	-46.8%	-53.7%	-102.6%	111.6%
Illiquid Savings (Low Type)	-100.0%	-100.0%	-74.6%	-67.0%	-60.8%	-55.5%	-49.5%	-43.6%	-39.4%
Illiquid Savings (High Type)	-100.0%	-78.4%	-60.3%	-56.4%	-52.7%	-48.6%	-44.5%	-39.9%	-36.5%

Due to computational limitations and the partial equilibrium nature of the model, my analysis is restricted to comparison of stationary distributions under various calibrations. First, I simulate a 1 percentage point decrease in the rate of return on illiquid wealth (from 5% to 4%), keeping all other parameters constant; results are shown in the distribution table above. Median consumption falls on average by 0.5% but this omits the distributional effects whereby consumption actually increases for the bottom 40% of households but decreases for the top 60% of households by net worth (sum of liquid and illiquid wealth). Median deposits turn negative from an initial value of 0 and overall were on average 1-2 times lower for all households of both types, indicating that households responded strongly to the lower return on illiquid assets by adjusting their portfolios toward the liquid asset. This consumption-saving behaviour is accurately reflected in the figures for liquid and illiquid savings. Median debt decreased by 20%-45% and all households had higher liquid wealth, or lower debt, regardless of type although the effect is quantitatively larger for households of the high type. Conversely, all households had correspondingly lower illiquid wealth with the bottom 20% (10% for high types) of households actually withdrawing all of their illiquid wealth. This meant that median illiquid wealth fell on average by 57%, a strong response to a relatively small change in the interest rate.

Percentile	10	20	30	40	50	60	70	80	90
Consumption (Low Type)	-1.3%	-0.7%	-0.1%	0.4%	1.2%	1.9%	2.3%	2.1%	1.4%
Consumption (High Type)	-1.1%	-0.5%	0.0%	0.5%	1.3%	1.8%	1.9%	1.7%	0.9%
Deposits (Low Type)	-16.2%	-43.1%	-86.7%	-100.0%	N/A	N/A	N/A	507.9%	147.9%
Deposits (High Type)	-21.2%	-57.8%	-100.0%	-100.0%	N/A	N/A	N/A	309.5%	130.2%
Savings (Low Type)	17.3%	18.4%	18.6%	17.9%	16.9%	15.4%	13.3%	11.1%	25.2%
Savings (High Type)	25.3%	29.3%	31.7%	33.2%	35.2%	36.8%	40.8%	51.7%	-31.7%
Illiquid Savings (Low Type)	221.9%	70.9%	60.6%	52.1%	48.0%	45.1%	42.9%	41.1%	36.5%
Illiquid Savings (High Type)	46.8%	45.0%	44.4%	42.6%	40.7%	39.7%	39.0%	37.0%	33.4%

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I also simulate a 1 percentage point increase in the rate of return on illiquid wealth (from 5% to 4%), keeping all other parameters constant. Median consumption rises on average by a stronger 1.2-1.3% but analogously, consumption decreased for the bottom 30% of households but increased for the top 70% of households. Median deposits also turned negative from an initial value of 0 and overall were on average 1-3 times lower for all households of both types, indicating that households responded strongly to the lower return on illiquid assets by adjusting their portfolios toward the liquid asset. Median debt increased by 17-35% and all households had lower liquid wealth, or higher debt. Conversely, all households had correspondingly higher illiquid wealth, though median illiquid wealth fell by a relatively smaller 44%.

Percentile	10	20	30	40	50	60	70	80	90
Consumption (Low Type)	-0.4%	-0.3%	-0.3%	-0.2%	-0.2%	-0.3%	-0.2%	-0.3%	-0.3%
Consumption (High Type)	-0.2%	-0.2%	-0.1%	-0.2%	-0.2%	-0.2%	-0.3%	-0.2%	-0.2%
Deposits (Low Type)	0.2%	4.4%	11.6%	25.4%	N/A	N/A	N/A	-40.8%	-16.6%
Deposits (High Type)	1.6%	7.7%	19.8%	66.1%	N/A	N/A	N/A	-25.2%	-14.7%
Savings (Low Type)	-1.9%	-2.1%	-2.1%	-2.2%	-2.1%	-2.0%	-1.8%	-1.8%	-3.1%
Savings (High Type)	-3.0%	-3.6%	-3.9%	-4.1%	-4.4%	-5.1%	-6.0%	-9.9%	9.9%
Illiquid Savings (Low Type)	7.9%	-3.5%	-2.4%	-4.6%	-4.1%	-3.2%	-3.4%	-3.1%	-2.7%
Illiquid Savings (High Type)	-1.4%	-3.2%	-3.7%	-3.6%	-3.5%	-3.0%	-3.0%	-2.7%	-2.4%

Next, I increase the fixed component of the transaction cost by 10% to simulate a reduction in the liquidity of the illiquid asset. Under this scenario, median consumption is substantially unchanged across the distribution, indicating a muted consumption response from households. On the other hand, there is significant portfolio rebalancing behaviour despite median deposits remaining close to 0. This is because the bottom 40% of households increased their deposits by up to 66% whilst households in the top 20% reduced their deposits by 15-41%, representing strongly heterogeneous responses by households to the change in liquidity. Median debt decreased by 2-4.5% and all households had lower liquid wealth, or higher debt, except for the top 10% of high types which increased their liquid savings by 10%. Conversely, all households had correspondingly lower illiquid wealth, except for the bottom 10% of low types which increased their illiquid wealth , though median illiquid wealth fell by a relatively smaller 44%.

5. Conclusion

This paper provides an application of recent advances in heterogeneous agent modelling to the UK economy with the aim of highlighting the policy-relevance of wealth inequality and its implications for aggregate outcomes. I introduce a theoretical model of household heterogeneity with the addition of an illiquid asset to the classical heterogeneous agent model generates a third type of household beyond the traditional spender and saver types, generally referred to as wealthy Hand-to-Mouth. These households face a trade-off between the higher returns offered on the illiquid asset and the transaction cost of depositing into that asset. This results in these households holding little to no liquid assets despite having a net worth resembling that of non HtM households. As a result, their consumption behaviour resembles that of households with relatively low net worth due to the introduction of this liquidity constraint that inhibits these households from smoothing consumption, thereby violating Ricardian equivalence.

I used data on the distribution of wealth to provide an updated empirical estimate for the fraction of HtM households in the UK. This showed that the share of HtM households is nearly 40% with more than two thirds of these being of the wealthy HtM type, note this is likely a lower bound estimate.

Identification and investigation of this new classification of household consumption behaviour is important for policymakers due to their high responsiveness to temporary income shocks, such as unconventional fiscal stimuli (Kaplan & Violante, 2014a). Therefore, in order to accurately forecast and analyse the impacts of fiscal and monetary policies, policymakers should understand the outsized influence of wealthy HtM households on aggregate outcomes. This is of particular importance because the canonical heterogeneous agent models of Aiyagari (1994) and Huggett (1996) include only one saving asset and therefore omit wealthy HtM behaviour entirely, assuming instead that they behave as non HtM households. Conversely, spender-saver, or TANK, models such as Campbell and Mankiw (1989) group wealthy HtM households in with poor HtM based on their behaviour

10.14324/111.444.2755-0877.1889

without accounting for the resilience of wealthy HtM households to smooth very large shocks using their illiquid wealth. The widespread use of one-asset and two-agent models may lead to misleading inference of consumption behaviour in response to transitory income shocks. An important implication of a two-asset model with transaction costs is the large asymmetry between the consumption responses of stimulus of different magnitudes. For very large stimuli, the HtM households of both types may optimally choose to pay the transaction cost in order to save the windfall into their illiquid assets. Whereas small stimuli may not be sufficiently large to make it optimal to pay the transaction cost despite the higher returns for illiquid assets. The policy conclusions of a model such as this are thus that there may be limited, or negative, marginal returns to increase the size of the stimulus. However, making stimuli available to more than just the poorest households, by net worth, may increase the aggregate consumption response by including higher net worth but still liquidity constrained households (Kaplan et al, 2014b). Following the pandemic, survey data indicates that many of the wealthiest households increased their savings rate whilst the poorest households were forced to dissave to smooth consumption following negative income shocks, albeit mitigated by the furlough scheme (Bank of England, 2020). Therefore, one might expect the fraction of poor HtM households to be even higher than estimated in this paper although the fraction of wealthy HtM households will depend crucially on the portfolio allocation decisions of those households so is broadly indeterminate.

Possible extensions may include, but are not limited to, more reliable and precise estimation of the fraction of HtM households in the UK, modelling the long-term transition effects of changes in fiscal and monetary policy in a partial equilibrium setting, and incorporating real and nominal rigidities such as labour market frictions and price stickiness into a general equilibrium two-asset model of the UK economy.

10.14324/111.444.2755-0877.1889

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