# Housing, Debt and the Marginal Propensity to Consume*

Preliminary Outline

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**Abstract**

We analyze how housing and mortgage debt affects households' marginal propensity to consume. Using detailed Norwegian register data, we document that after controlling for wealth, households with higher leverage increase consumption more when their wealth changes. Hence, for the purpose of understanding household consumption dynamics, wealth is an insufficient statistic to summarize household balance sheets. We therefore develop a structural model to account for how household accumulate mortgage debt over the life cycle, and how this affects consumption choice. In our model, households hold debt, financial assets and illiquid housing. The marginal propensity to consume out of wealth is declining, as in a standard single asset consumption model, but not monotonically so: households who have recently bought houses have high leverage and high marginal propensities to consume. We estimate the model to account for the life cycle profiles of household balance sheets in the micro data. Regressions from data simulated by the model give results consistent with regressions on the actual register data. Our findings corroborate the view that household indebtedness and leverage matter for consumption dynamics, that a substantial fraction of households are likely to behave in a "hand-to-mouth" fashion even though their wealth is high, and that the housing market is key to these phenomena.

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# 1 Introduction

Household mortgage debt is ubiquitous. According to the recent wave of Survey of Consumer Finances, 74.5% of U.S. families have debt and 41.5% have mortgages or home equity loans in 2013. Many economists have argued that high levels of household debt have played a role in suppressing aggregate consumption and thus propagating the Great Recession. Mian, Rao, and Sufi (2013) provide evidence in this direction, finding that during the Great Recession, aggregate consumption responded more to wealth losses in ZIP code areas where leverage was high. Still, the underpinnings of how debt affects consumption dynamics are limited, as most of the evidence and the discussion to date has taken place at an aggregate level. It is therefore natural to ask, at the micro level, how and why does debt influence consumption?

In this paper we aim to develop a structural model of household behavior that can quantitatively account for reduced form evidence on how leverage affects the marginal propensity to consume out of wealth changes. To this end, we utilize detailed Norwegian registry data of household balance sheets and imputed consumption and proceed in two steps. First, we explore if the link between leverage and the marginal propensity to consume out of wealth changes, which previously has been documented at the macro level in a recession episode, also holds at the micro level in normal times. We find that it does. After controlling for wealth, households with higher leverage have a larger consumption response to wealth changes. Second, we proceed to our main objective, to develop a structural model that can account for the typical life cycle profile of households' balance sheets, and compare the model-implied relationship between household leverage and consumption to that in the data.

Canonical consumption theory does not distinguish between different asset classes on household balance sheets. The implicit assumption is that only total wealth affects their consumption decisions. Debt then matters only insofar as it affects net worth. In the data, however, there is substantial heterogeneity in household balance sheets. Figure 1 contrasts leverage to wealth for Norwegian households between 2006 and 2010. For any given level of wealth, leverage varies a great deal. This is what allows us to estimate the role of leverage, over and beyond its relation to net worth. Moreover, it is clear that we must move beyond the benchmark single-asset model of consumption, and use a model with a richer balance sheet. We develop a model which differentiates between the three main asset classes held by Norwegian households: Debt, other financial assets, and housing. Our model is then estimated to capture the life cycle profiles of balance sheets in the data.

We argue that in order to account for the typical life cycle profile of debt

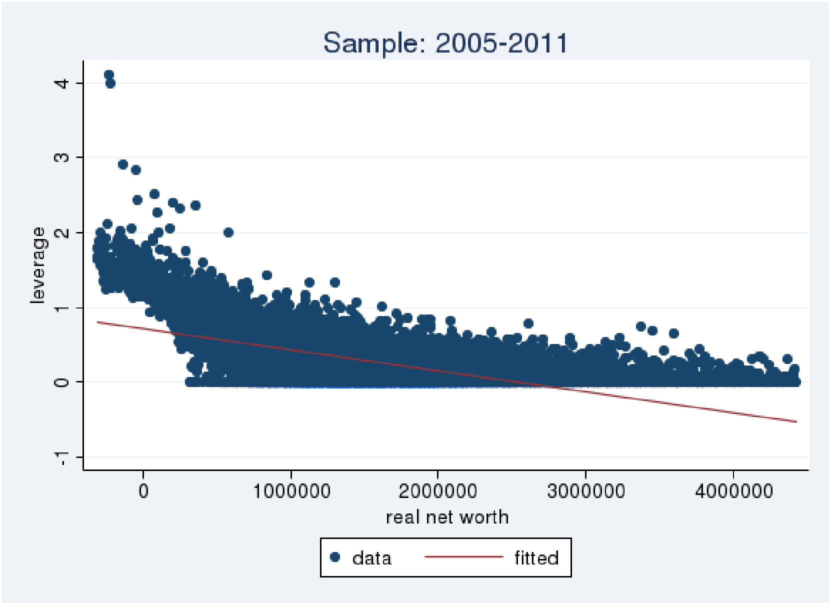


Figure 1: Heterogeneity in Household Leverage and Wealth
Leverage in this context is defined as the ratio of debt to housing value. Real wealth is in 2005 NOK. As tax implied housing value is systematically lower than market value in Norway, there are a great many observations whose leverage exceeds one. However, the very shape of leverage against wealth implies the consistency of the under reporting of housing value, suggesting that our analysis is less likely to be affected.

in the data, housing decisions are key. Typically, households accumulate financial assets for some time, before making discrete house purchases which are largely financed by debt. They tend to re-balance their portfolio between housing and other assets very infrequently. Our model therefore treats housing decisions in some detail, and distinguishes home ownership from renting. Households are subject to uninsurable idiosyncratic labor income risk and borrowing constraints. In each period, renters allocate intratemporal consumption between non-housing consumption and housing service (rental payments); homeowners only make decisions about non-housing consumption while enjoying the service flow of their housing. Renters can decide to become homeowners next period. Homeowners can choose to become a renter or to buy a different house. However, there are transaction costs associated with buying and selling houses.

The existence of transaction costs makes homeowners move infrequently. Purchases of larger houses will be largely financed with debt, and buyers who are expanding their housing stock will move close to their borrowing constraint. Hence, homeowners who have recently expanded their housing stock will have high leverage, and a composition of their consumption basket that is highly intensive in housing. Yet, they are relatively unwilling to adjust their housing consumption due to the transaction costs. The combination of proximity to the borrowing constraint and high transaction costs, raises these households' marginal propensity to consume out of wealth and income shocks. In fact, households' MPC does not monotonically decrease in wealth; a recent homebuyer has a higher MPC than she had right before buying the house, even though there is no change in her wealth. Households with larger houses and more debt tend to have higher MPC than those with a smaller balance sheet. We thus see that the housing decision is essential both for our model to capture the life cycle evolution of household balance sheets, and for its ability to capture how the marginal propensity to consume is related to leverage.

The rest of the paper is organized as follows. Section 2 reviews related literature. Section 3 provides a description of the Norwegian registry data and discusses empirically the role of leverage in the consumption response to wealth changes. In section 4, we use a simple two-period model to illustrate why leverage might give rise to potentially high marginal propensity to consume. In section 5, we develop a full-fledged consumption-saving model with housing, debt and financial assets, and we show that a calibrated version of this model is able to capture the typical composition of a household's balance sheet over the life cycle and generate a reasonable marginal propensity to consume. Section 6 concludes.

## 2 Relation to the Literature

Our paper is closely related to three strands of literature. The sluggish recovery after the recent Great Recession in the U.S. and elsewhere in the world has raised questions of whether high levels of household leverage impeded consumption growth over and above what the observed wealth changes in themselves would imply. Empirically, using household-level data, Dynan, Mian, and PENCE (2012) find that highly leveraged homeowners had larger declines in consumption than other homeowners between 2007 and 2009. Mian, Rao, and Sufi (2013) use zip-code level auto sales data and find that the consumption response to housing wealth changes was larger in zip codes with poorer and more levered households. Our empirical analysis complements this literature by using novel Norwegian registry data at the household level. We focus on the period between 2005 and 2011 as the housing wealth measure is the most accurate in this period. While the U.S. and Europe were greatly hit by the Great Recession, the impact on Norway is relatively small during this period. Thus, the role of leverage we highlight is not limited to recessions. On the theoretical side, most of the literature studying leverage and consumption focuses on how a credit crunch reduces consumption for constrained households (for instance, Eggertsson and Krugman (2012), Guerrieri and Lorenzoni (2011)). In these models, an exogenous reduction in the debt limit amounts to an increase in wealth; deleveraging is forced and there is no propagating role for debt and leverage. In our model, households with higher leverage have higher consumption response to wealth changes, and thus would optimally choose to de-lever more when wealth declines.

Our paper is closely related to an old literature revived recently on excess sensitivity with respect to transitory shocks. There is mounting evidence that the marginal propensity to consume out of transitory shocks is well above zero. Using a macroeconomic model that matches the wealth distribution in the U.S., Carroll, Slacalek, and Tokuoka (2014) show that the MPCs can be much larger than those implied by off-the-shelf representative agent models. However, for households with the same preferences in this model, it is essentially the poor households who exhibit the largest MPCs. Our model shows that even with the same preferences, the MPC might not decline monotonically in wealth. The presence of durable purchases, especially housing, induces a high MPC for rich households. Kaplan and Violante (2014) show that high returns on illiquid assets induce hand-to-mouth behavior among wealthy households. Our model of housing is similar to theirs. In our model, however, households prefer home ownership because it provides more utility than renting. Thus our results do not rely on excess return on housing. In addition, there is no explicit transitory shocks in their model, but as emphasized in Deaton (1991), the presence of transitory shocks can affect wealth accumulation to a great extent. We explicitly consider transitory shocks in our model. In our case, transitory shocks give rise to a dispersion of income and wealth for households with the same permanent income of the same age. The dispersion is important for the timing of housing transactions. Without transitory shocks, households tend to move together, creating discrete jumps in homeownership rate.

The third strand of literature that our paper connects to is one on life cycle choices. Gourinchas and Parker (2002) and Cagetti (2003) estimate structural preference parameters of life cycle models of consumption and saving. Fernandez-Villaverde and Krueger (2011) studies the durable and nondurable consumption over the life cycle. Yang (2009) explains housing and non-housing consumption profiles over the life cycle. While these papers are centered on consumption and saving patterns over the life cycle, we focus on the implications for the heterogeneity in consumption response to wealth changes. We estimate the structural parameters of our model by matching the housing and liquid asset levels of a median household over the life cycle in the data, and we show that the estimated model leverage implies reasonable MPCs and a similar propagating role of leverage as in the data.

On the technical side, we use a modified version of the endogenous grid point method Carroll (2006) to solve our model. Unlike the common practice of using value function iterations to solve dynamic stochastic optimization models, the endogenous grid point method allows us to solve the model quickly and accurately and permits the estimation of a structural model within a reasonable amount of time. As our model involves non-convex transaction costs, discrete and continuous choices, and occasionally binding constraints, our modified version of endogenous grid point method contains elements of Iskhakov, Jørgensen, Rust, and Schjerning (2014), Fella (2014), and Hintermaier and Koeniger (2010).

# 3 Balance Sheet Over the Life Cycle

## 3.1 The Norwegian Registry Data

In Norway there are no microeconomic data on consumption other than the consumer expenditures survey (CES). This survey included a small fraction of households that were included only in two consecutive years. For these households we have data on consumer expenditures and disposable incomes that make it possible to estimate models discussed earlier. However, the number of observations is very small. In addition the CES has recently been terminated because of data quality problems relating both to selection as well as the consumption expenditures data in itself. However, Norway has very good administrative data on income and wealth that may be used to construct consumption as a residual of income net of taxes and saving.

The Norwegian administrative micro-data on income and wealth reports wealth every year, and not only every 4 years as in the PSID. Thus we are able to estimate consumption as the residual of disposable income and savings without having to estimate wealth as well. Based on previous work on the data, by Fagereng and Halvorsen(2015), we have a database covering all the data needed for estimating saving and consumption for Norwegian households from 1993 to 2011. Our method will be comparable to and along the lines of the work done by Browning and Leth-Pedersen (2003) and Koijen et al. (2012). They imputed consumption from Danish and Swedish registry data repectively, and concluded that the results were promising.

We combine information from Norwegian registry data on income, asset holdings, and asset returns to arrive at imputed consumption expenditure from the household budget constraint. Consumption of household $i$ in period $t$ is constructed as income minus savings:

$$
\begin{aligned}
c_{it} &= y_{it} - s_{it} \\
c_{it} &= yl_{it} + r^f_{it} a^f_{it-1} + r^r_{it} a^r_{it-1} - r^d_{it} d_{it} - (\Delta a_{it} - \Delta d_{it}) \qquad (1)
\end{aligned}
$$

where we have in the second line separated income[1] into labor income including pensions and public transfers, $yl$, and capital income $(r^f_{it} a^f_{it-1} + r^r_{it} a^r_{it-1} - r^d_{it} d_{it})$, and savings into the first difference in financial asset $\Delta a_{it}$ and the first difference in debt $\Delta d_{it}$. Capital income $r^f_{it} a^f_{it-1}$ is after-tax financial asset income (interest on bank accounts, coupons from bonds, dividends from stocks, and income from stock option contracts). The rate $r^d_{it}$ is the family specific interest rate on debt between $t$ and $t-1$, and $r^f_{it}$ is the family specific return on the asset portfolio held between $t$ and $t-1$. We will include imputed rents $\left(r^r_{it} a^r_{it-1}\right)$ as part of our income definition, but not capital gains on housing. The savings variable is separated into total debt ($d$) and assets ($a$) where $\Delta d_{it} = d_{it} - d_{it-1}$ and $\Delta a_{it} = a_{it} - a_{it-1}$. Financial assets consists of bank accounts, stocks (listed and non-listed), bonds, mutual funds, moneymarket funds, cash value of life insurance, contributions to private pension accounts and other financial assets. Income that is not invested or used to reduce debt, declines in net asset values, and net increases in debt all translate into higher consumption. The richness of the Norwegian data makes all terms on the right-hand side of equation (1) observable. For a detailed description of the data, see Fagereng and Halvorsen (2015). All amounts are denoted in real terms (with base year 2000), where the deflator is the Norwegian consumer price index.

### 3.1.1 Administrative Tax records

Because households in Norway are subject to a wealth tax, they are required to report every year their complete wealth holdings to the tax authority, and the data are available every year from 1993 up until present time.[2] Each year, before taxes are filed (the year after) in April, employers, banks, brokers, insurance companies and any other financial intermediaries are obliged to send both to the individual and to the tax authority, information on the value of the asset owned by the individual and administered by the employer

[1]All incomes are assumed to be after tax values. Taxes are computed using tax functions.

[2]In Norway the individuals in a household are taxed jointly when it comes to the wealth tax, while separately for the income tax.

or the intermediary, as well as information on the income earned on these assets. In case an individual holds no stocks, the tax authority pre-fills a tax form and sends it to the individual for approval; if the individual does not respond, the tax authority considers the information it has gathered as approved. In 2009, as many as 2 million individuals in Norway (60% of the tax payers) belonged to this category. If the individual or household owns stocks then he has to fill in the tax statement - including calculations of capital gains/losses and deduction claims. The statement is sent back to the tax authority which, as in the previous case receives all the basic information from employers and intermediaries and can thus check its truthfulness and correctness. Stockholders are treated differently because the government wants to save on the time necessary to fill in more complex tax statements. This procedure, particularly the fact that financial institutions supply information on their customer's financial assets directly to the tax authority, makes tax evasion very difficult, and thus non-reporting or under-reporting of assets holdings are likely to be negligible.

Cars, boats and other motor vehicles are reported in the tax record with standardized list values depending on brand and year of production. The list value in the first year after purchase is about 75% of the market value, thereafter most list values decline on average 10 percentage points each year. Where the depreciation is not already given by declining tax values, we compute an annual depreciation rate of 10 percent.

### 3.1.2 Housing values

Income from housing in the income tax base was abolished in 2005 in Norway. However, the imputed income was based on tax values for housing that had a weak relation to actual market prices. The same tax values were used as a basis for the wealth tax. Tax values for housing for the period 1993-2009 were on average about 20% of market prices. Individual variation was primarily linked to the construction year of the house. Old, refurbished villas in attractive neighborhoods could in some cases have tax values close to zero. Furthermore, the tax values were adjusted irregularly. As a result, the tax values were not useful as approximations of actual housing values. However, imputations of housing values based on hedonic price regressions are available from 2005 (see Thomassen and Melby 2009; Kostøl and Holiløkk 2010). From 2010 these values were also implemented as basis for wealth taxation in the tax records (that is, the tax value is set to 25% of the imputed market value). In the imputation of consumption we define one measure using these data from 2005 to 2011. To mitigate potential measurement errors in household assets we exclude year observations of households that have reported relocation to the address register, since this is likely to be years in which the household has traded housing (where we would observe fully the change in mortgage but not the corresponding purchase or selling price).

The housing stock also depreciates over time, but unlike cars and household durables, it rarely deteriorates completely. Instead, it is common to undertake irregular major refurbishment in order to get the housing stock in line with modern standards. This lumping of maintenance costs, often financed by remortgaging, represents a measurement problem in our data since the market value does not represent the exact individual housing values. Market housing values, when available, are based on housing attributes such as location, type, size and age.

Holiday homes, on the other hand, are still reported with tax values that are far below actual market values. This is why we also choose to exclude year observations of households who trade vacation homes.

### 3.2 Housing Leverage and the Wealth Effect on Consumption

In this section, we empirically explore if leverage, defined as the debt-to-housing ratio, affects households' consumption response to wealth changes. Compared to Mian, Rao, and Sufi (2013), who address this question at a more aggregate level using ZIP code areas during a particular episode (the Great Recession), our contribution is to utilize micro data in a more tranquil environment.

As a starting point, consider the consumption function in standard buffer-stock saving models with only one asset, of the type surveyed by Heathcote, Storesletten, and Violante (2009). In such models, labor income uncertainty gives households a precautionary motive. Consumption $C_t$ is an increasing function of wealth $W_t$ (inclusive of current labor income), i.e., $C_t = \mathcal{C}(W_t)$. Wealth, $W_t$, is the state variable that summarizes household balance sheet at time $t$. Importantly, the precautionary motive implies that $\mathcal{C}(\cdot)$ is concave (Carroll and Kimball (1996)). As a result, a household's consumption response to wealth changes, $\frac{dC_t}{dW_t}$, depends on its wealth level $W_t$.

To study the role of debt, we define leverage as the ratio of household debt over housing value:

$$lev_t = \frac{B_t}{H_t}$$

We then explore if leverage matters for the marginal propensity to consume out of wealth changes, by estimating

$$\Delta C_{it} = \beta_0 + \beta_1 \Delta W_{it} + \beta_2 W_{it-1} + \beta_3 \Delta W_{it} \times W_{it-1} + \beta_4 lev_{it-1} + \beta_5 \Delta W_{it} \times lev_{it-1} \quad (2)$$

From the standard buffer-stock saving model, we should expect that $\beta_3 < 0$ due to the concavity of the consumption function. We would also expect that $\beta_5$ is insignificant, as wealth is a sufficient summary statistic of the household balance sheet upon which consumption depends. Our key parameter of interest in Equation (2) is $\beta_5$. That is, after controlling for household wealth levels, does the composition of households' balance sheet matter for their consumption response to wealth changes, $\beta_5 \neq 0$?

Table 1 shows that leverage does indeed play such a role. Column (1) of Table 1 estimates the concavity of the consumption function in the Norwegian data. The estimated coefficient on the interaction term, $\beta_3$ in equation (2), is negative and statistically significant, indicating that consumption is indeed concave in wealth, in line the standard buffer-stock saving model. Column (2) adds leverage and its interaction with wealth changes. We see that the estimated interaction coefficient, $\beta_5$ in equation (2), is positive and statistically significant. Not only is this coefficient highly significant, it is economically important. For instance, consider a household who recently bought its first house, largely financed by debt as typically is the case for first-time home buyers. Its wealth level has barely changed, but its balance sheet composition changes dramatically. In particular, this household's leverage jumps from zero to almost one. Our coefficient estimate implies that this household's marginal propensity to consume out of a 1 dollar wealth change would increase by almost 21 cents.

Columns (3)-(6) adds income and age polynomials to the regression. In particular, we want to address the concern that leverage is picking up the effect of income expectations. It is possible that households who expect higher future income want to take on more leverage, and as their current wealth is low relative to lifetime income, they have higher marginal propensity to consume out of wealth changes. In column (3) and (4), average income proxies for households' permanent income before wealth changes, and in column (5) and (6), average income and age polynomials together capture the deterministic profile of household income over the life cycle and thus serve to proxy for households' income expectations. The estimates in column (4) and (6) indicate that expected income is not driving our results. The coefficient on the interaction term between leverage and wealth changes, $\beta_5$ in equation (2), increases slightly and remains highly significant.

The consumption function $\mathcal{C}(\cdot)$ discussed above is the same for all households, and should be interpreted as a combination of consumption functions of households with different permanent income. In standard buffer-stock saving models with only heterogeneity in labor income, the ratio of wealth to permanent income is a summary statistic to predict consumption responses to wealth changes, as it measures the wealthiness of households in terms of their lifetime income. Table 2 presents the results from regression equation (2) with $M_{t-1}$ replaced by $M_{t-1}/Y_{t-1}$. The results are similar, and now $\beta_3$ for all regressions are negative. This is because the consumption function is essentially concave in the wealth to income ratio rather than the wealth level.

The influence of leverage, over and beyond its correlation with wealth, can not be explained within the single-asset buffer-stock model of household consumption. The remainder of this paper therefore seeks to develop a structural model that can account for why leverage matters.

## 4 Leverage in a Simple Model

To illustrate the mechanism that will be important in our quantitative model, we start with a simple environment. Households live three periods $t = 0, 1, 2$. At $t = 0$, households have cash on hand $M_0$ and there are houses of size $H$ available for purchase. At $t = 1$, households receive deterministic income $Y_1$ and at $t = 2$ households receive stochastic income $Y_2$.[3] Households derive utility in $t = 1, 2$. Their lifetime utility is

$$V = u(\tilde{C}_1) + \beta E_0 \left[ u(\tilde{C}_2) \right],$$

where $C_t$ is a consumption index of non-housing consumption $C_t$ and housing service flow $S_t$, and $u(\cdot)$ is their instantaneous utility function. For simplicity, we assume

$$u(\tilde{C}_t) = \log(\tilde{C}_t)$$
$$\tilde{C}_t = C_t^{\alpha} S_t^{1-\alpha}$$

At $t = 0$, households have two options. They may either purchase the house at cost $H$ and enjoy the service flow $\zeta H$ in both future periods, or they may simply decide to rent in $t = 1, 2$. To simplify the argument, we assume that if households buy the house, they will keep it at all times. Households' budget constraint under each option is

[3] It does not matter for the results whether $Y_1$ is stochastic or not.

| | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ |
|---|---|---|---|---|---|---|
| $\Delta W_t$ | 0.529*** | 0.349*** | 0.489*** | 0.343*** | 0.506*** | 0.655*** |
| | (0.001) | (0.002) | (0.001) | (0.002) | (0.023) | (0.023) |
| $W_{t-1}$ | -0.000 | -0.042*** | 0.004*** | -0.050*** | 0.010*** | -0.046*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| $\Delta W_t \times W_{t-1}$ | -0.016*** | 0.019*** | -0.038*** | -0.003*** | -0.052*** | -0.016*** |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| $lev_{t-1}$ | | -0.156*** | | -0.175*** | | -0.202*** |
| | | (0.001) | | (0.001) | | (0.001) |
| $\Delta W_t \times lev_{t-1}$ | | 0.210*** | | 0.165*** | | 0.182*** |
| | | (0.002) | | (0.002) | | (0.002) |
| $\bar{Y}$ | | | -0.091*** | 0.074*** | -0.106*** | 0.051*** |
| | | | (0.001) | (0.002) | (0.002) | (0.002) |
| $\Delta W_t \times \bar{Y}$ | | | 0.204*** | 0.174*** | 0.204*** | 0.175*** |
| | | | (0.002) | (0.002) | (0.002) | (0.002) |
| $age$ | | | | | 0.001** | 0.009*** |
| | | | | | (0.000) | (0.000) |
| $\Delta W_t \times age$ | | | | | -0.012*** | -0.029*** |
| | | | | | (0.001) | (0.001) |
| $age^2$ | | | | | -0.006*** | -0.022*** |
| | | | | | (0.001) | (0.001) |
| $\Delta W_t \times age^2$ | | | | | 0.038*** | 0.068*** |
| | | | | | (0.003) | (0.003) |
| $age^3$ | | | | | 0.004*** | 0.014*** |
| | | | | | (0.000) | (0.000) |
| $\Delta W_t \times age^3$ | | | | | -0.028*** | -0.043*** |
| | | | | | (0.002) | (0.002) |
| _cons | -0.021*** | 0.102*** | -0.001* | 0.099*** | 0.022*** | 0.042*** |
| | (0.000) | (0.001) | (0.001) | (0.001) | (0.008) | (0.008) |
| adj. $R^2$ | 0.284 | 0.316 | 0.291 | 0.319 | 0.297 | 0.331 |
| N | 1,583,209 | 1,583,209 | 1,583,209 | 1,583,209 | 1,583,209 | 1,583,209 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1: The Role of Leverage in Consumption Response to Wealth Changes

| | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ |
|---|---|---|---|---|---|---|
| $\Delta W_t$ | 0.581*** | 0.451*** | 0.515*** | 0.369*** | 0.655*** | 0.675*** |
| | (0.001) | (0.002) | (0.002) | (0.002) | (0.024) | (0.023) |
| $\frac{W_{t-1}}{Y_{t-1}}$ | 0.002*** | -0.006*** | 0.000*** | -0.008*** | 0.001*** | -0.007*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| $\Delta W_t \times \frac{W_{t-1}}{Y_{t-1}}$ | -0.012*** | -0.006*** | -0.009*** | -0.002*** | -0.012*** | -0.004*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| $lev_{t-1}$ | | -0.141*** | | -0.146*** | | -0.177*** |
| | | (0.001) | | (0.001) | | (0.001) |
| $\Delta W_t \times lev_{t-1}$ | | 0.164*** | | 0.171*** | | 0.194*** |
| | | (0.002) | | (0.002) | | (0.002) |
| $\bar{Y}$ | | | -0.085*** | -0.111*** | -0.082*** | -0.115*** |
| | | | (0.002) | (0.002) | (0.002) | (0.002) |
| $\Delta W_t \times \bar{Y}$ | | | 0.111*** | 0.128*** | 0.093*** | 0.109*** |
| | | | (0.002) | (0.002) | (0.002) | (0.002) |
| $age$ | | | | | 0.001* | 0.011*** |
| | | | | | (0.000) | (0.000) |
| $\Delta W_t \times age$ | | | | | -0.017*** | -0.029*** |
| | | | | | (0.001) | (0.001) |
| $age^2$ | | | | | -0.004*** | -0.027*** |
| | | | | | (0.001) | (0.001) |
| $\Delta W_t \times age^2$ | | | | | 0.045*** | 0.067*** |
| | | | | | (0.003) | (0.003) |
| $age^3$ | | | | | 0.003*** | 0.017*** |
| | | | | | (0.000) | (0.000) |
| $\Delta W_t \times age^3$ | | | | | -0.030*** | -0.041*** |
| | | | | | (0.002) | (0.002) |
| _cons | -0.034*** | 0.068*** | 0.002*** | 0.117*** | 0.023*** | 0.041*** |
| | (0.000) | (0.001) | (0.001) | (0.001) | (0.008) | (0.008) |
| adj. $R^2$ | 0.289 | 0.312 | 0.292 | 0.317 | 0.297 | 0.330 |
| N | 1,583,209 | 1,583,209 | 1,583,209 | 1,583,209 | 1,583,209 | 1,583,209 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2: The Role of Leverage in Consumption Response to Wealth Changes Controlling for Wealth to Income Ratio

*To own*

$$
\begin{aligned}
t &= 0 \qquad & A_0 &= M_0 - H && (3)\\
t &= 1 \qquad & A_1 &= A_0 + Y_1 - C_1 && (4)\\
t &= 2 \qquad & C_2 &= (1+r)A_1 + Y_2 && (5)\\
& & & && (6)
\end{aligned}
$$

*To rent*

$$
\begin{aligned}
t &= 0 \qquad & A_0 &= M_0 && (7)\\
t &= 1 \qquad & A_1 &= A_0 + Y_1 - C_1 - S_1 && (8)\\
t &= 2 \qquad & C_2 + S_2 &= (1+r)A_1 + Y_2 && (9)
\end{aligned}
$$

In deciding whether to buy or to rent, households face a trade-off. On the one hand, owning can be cheaper than renting, for the same housing service flow, if $\zeta$ is high, which gives households an incentive to own[4]. On the other hand, the purchase of housing would reduce the liquid resources available to finance non-housing consumption, which is costly in bad states of the world when marginal utility of non-housing consumption is high. This is the motivation for renting. Hence, at $t = 0$ there is a threshold level of cash on hand, $M*$, which determines housing choice. When households are rich at $t = 0$, $M_0 > M^*$, they would be willing to purchase the house; when they are poor, $M_0 < M^*$, households would choose to rent. The top graph in Figure 2 displays the value functions of the two options. The red dashed line is the value function of renting while the blue dashed line is the value function of owning. To the left of $M^*$, households derive more utility from renting than owning. To the right, owning is more favorable than renting. The black solid line is the value function of households at $t = 0$, which is the upper envelope of the value functions of renting and owning.

The choice of renting or owning would have implications for non-housing consumption and the marginal propensity to consume in $t = 1$. Importantly, the envelope theorem states that $\frac{dV}{dM_0} = u'(\tilde{C}_1)\frac{\partial \tilde{C}_1}{\partial C_1}$. Because the value function has a kink at $M^*$, there is an upward jump in the marginal value of wealth $\frac{dV}{dM_0}$ at $M^*$. But by the envelope theorem, the marginal value of wealth is equal to the marginal utility of non-housing consumption. Thus

[4]Note that the only reason households would buy a house in this model is that $\zeta$ is high. In other words, homeownership provides more service flow than renting for any size of housing. In this simple model, housing is a less profitable asset than cash, as it earns zero return while the return to cash is $r$. When there is possible capital gains on housing, it is more attractive to purchase a house.

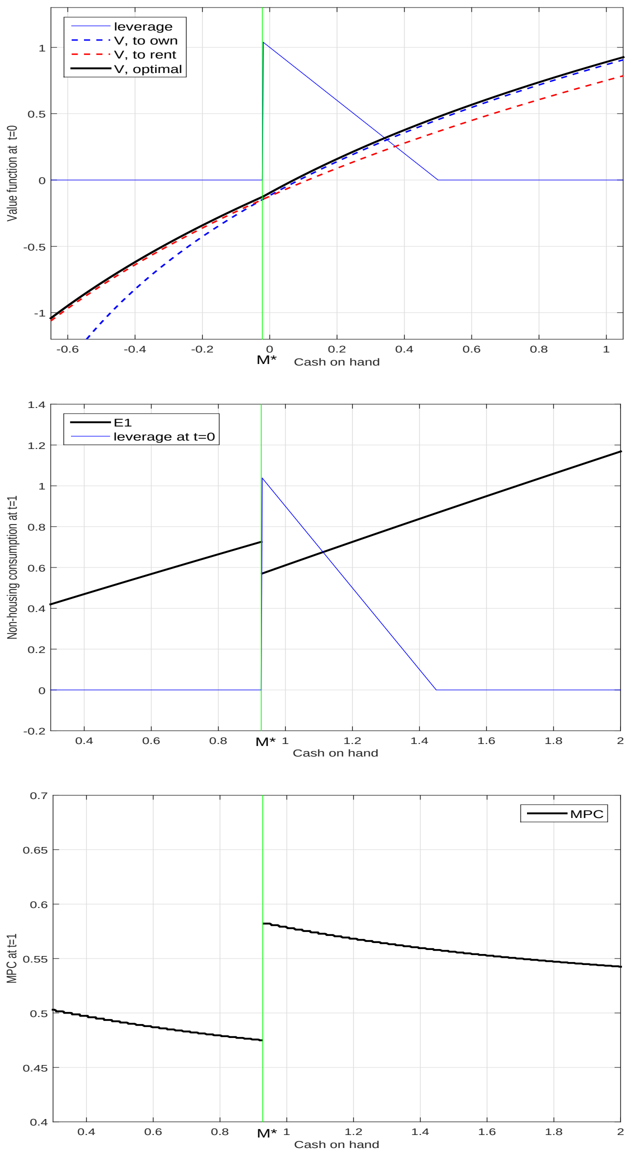


Figure 2: Leverage in a simple model
Parameters: $\zeta = 0.8, r = 0.03, \alpha = 0.85, \beta = 0.96, H = 0.5$. $Y_1$ and $Y_2$ are stochastic with mean value 1. In the top graph, the black solid line is the value function of households who optimally choose between renting and owning. It is the upper envelope of the red and the blue dashed lines, which are the implied value functions of renting and owning respectively. The blue line is the optimal leverage. The middle graph plots the non-housing consumption function when $Y_1 = 0.95$ while the bottom graph plots the corresponding marginal propensity to consume.

there is also an upward jump in the marginal utility of non-housing consumption and therefore a downward jump in non-housing consumption at $M^*$, as is seen in the middle graph in Figure 2. This downward jump implies an increase in the marginal propensity to consume. Intuitively, by being a renter, households are able to smooth total consumption on both non-housing and housing consumption margins at $t = 1, 2$. In contrast, by committing themselves to a house at $t = 0$, households are only able to smooth their non-housing consumption at later dates. As a result, owners have higher marginal propensity to consume than renters. This is different from standard life cycle models where there is only one asset in two aspects. First, whereas standard life cycle models imply that the MPC decreases in cash on hand, our simple model implies that the MPC is not monotonic in cash on hand: housing purchase would induce kinks in the value function and give rise to a jump in the MPC. Second, and perhaps more importantly, standard life cycle model would imply very low MPC for wealthy households; our model suggests their MPC could be much higher.

In our model, controlling for cash on hand, leverage captures the kink in the value function. In Figure 2, households slightly to the right of $M^*$ would have much higher leverage than households slightly to the left, yet they almost have the same cash on hand. Thus in the data, we should expect households with higher leverage to have higher consumption response to wealth changes, keeping cash on hand constant.

In fact, the effect of leverage is more general and stronger than it appears in this simple model. First, in the current model, leverage captures the contrast between the choices of renting and owning. It is plausible that in a model with a wide range of housing available, leverage would also capture the contrast between households who choose low levels of housing and high levels of housing. Second, households in the current model are not allowed to sell their house at $t = 2$. The possibility of capital gains would make housing more valuable and would induce an even greater jump in the MPC. Third, there is no collateral constraint in the current model. The existence of a collateral constraint could push the MPC of the liquidity constrained households to the right of $M^*$ even higher.

## 5 A Consumption-Saving Model

In this section, we develop a full-fledged consumption-saving model with housing, debt, and financial assets. We then estimate our model in two steps. The first set of parameters are estimated externally. In the second step, we use the simulated method of moments to estimate the rest of the parameters such that our simulated median profiles of housing, debt and financial asset match the data. Finally, we discuss the implications of our model for the role of leverage in explaining heterogeneity of households' consumption response to wealth changes.

### 5.1 The Model

Each household solves the dynamic stochastic optimization problem

$$u(\tilde{C}_{a_0}) + E_{a_0}\left[\sum_{a=a_0+1}^{T} \beta^{a-a_0}\left(p_a^S u(\tilde{C}_a) + (1-p_a^S)u^d(W_a)\right)\right] \tag{10}$$

where $\beta$ is the discount factor, $p_a^S$ is the unconditional probability of survival at age $a$. Households have constant relative risk aversion (CRRA) utility function

$$u(\tilde{C}_a) = \frac{\tilde{C}_a^{1-\rho}}{1-\rho} \qquad \rho > 1 \tag{11}$$

and derive utility from a consumption index with a constant elasticity of substitution (CES)

$$\tilde{C}_a = \left[\alpha^{\frac{1}{\theta}} C_a^{\frac{\theta-1}{\theta}} + (1-\alpha)^{\frac{1}{\theta}} S_a^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{12}$$

where $C_a$ is non-housing expenditure and $S_a = \zeta H_a$ is the service flow from housing. $H_a$ is the real value of owner-occupied housing and $\zeta$ is the real rental value of housing. When there is positive probability of death, households derive additional utility from leaving a bequest. We assume that the utility from bequest follows

$$u^d(W_{a+1}) = \varphi \frac{W_{a+1}^{1-\rho}}{1-\rho}$$

where $W_{a+1}$ is wealth upon death and $\varphi$ is the relative weight with which households value bequests.

*Income Process*

Households have a permanent-transitory type of income process.

$$Y_a = P_a \Xi_a \tag{13}$$

$$P_a = \Gamma_a P_{a-1} \Psi_a \tag{14}$$

where $Y_a$ is the after-tax income, $P_a$ is the permanent component of income and $\Xi_a$ is the transitory component of income at age $a$. $\Gamma_a$ is the deterministic growth rate of permanent income, and $\Psi_a$ is the permanent shock to income. We assume that transitory and permanent shocks are log-normally distributed

$$\xi_a = \log \Xi_a \sim N(-\frac{\sigma^2_{\xi,a}}{2}, \sigma^2_{\xi,a}) \tag{15}$$

$$\psi_a = \log \Psi_a \sim N(-\frac{\sigma^2_{\psi,a}}{2}, \sigma^2_{\psi,a}) \tag{16}$$

*Renters and Homeowners*

Households can either rent or live in a house. The price of housing service flow relative to non-housing expenditure is $p^h_a$. Renters choose non-housing expenditure $C_a$ and housing service $S_a$ in each period. Their intratemporal budget constraint is

$$C_a + p^h_a S_a = X_a$$

where $X_a$ is total spending at age $a$. Homeowners, in contrast, enjoy their housing, and all of their expenditure at the age of $a$ is non-housing expenditure.

*Moving*

Renters can decide to become homeowners or remain renters in the next period; homeowners can stay in their current house, move to another house, or become a renter in the next period. For transparency, we denote the five types of movements between renters and homeowners as $rr$, $rh$, $hr$, $hh$ and $hh'$ respectively. There is a transaction cost associated with housing purchase and sale ($rh$, $hr$ and $hh'$). In particular, we assume that $\kappa_p$ and $\kappa_s$ are proportional transaction costs of purchase and sale. As for most people a housing transaction is a project that takes time, energy and human resources, there is an opportunity cost. We assume it is a proportion $\kappa$ of each household's permanent income.

*Borrowing and Constraints*

The borrowing rate $r_b$ is higher than the risk free interest rate $r$. There are three types of constraints: unsecured borrowing where households are able to borrow up to a certain amount of their permanent income

$$A_a \geq -\mu_U P_a \tag{17}$$

the loan to value constraint

$$A_a \geq -\mu_V p^h_a H_{a+1} \tag{18}$$

and the loan to income constraint

$$A_a \geq -\mu_Y PV_a \tag{19}$$

where $PV_a = E_t\left[\frac{Y_{a+1}}{1+r_b} + \cdots + \frac{Y_T}{(1+r_b)^{T-a}}\right]$ is the present value of expected income in the future. With respect to a household's end-of-period asset, the loan to value constraint states that debt cannot be greater than a certain fraction of its current housing value while the loan to income constraint stipulates that debt cannot exceed a certain fraction of the household's expected income in the future.

To summarize, the households' problem is

$$\max u(\tilde{C}_{a_0}) + E_{a_0}\left[\sum_{a=a_0+1}^{T} \beta^{a-a_0}\left(p_a^S u(\tilde{C}_a) + (1-p_a^S)u^d(W_a)\right)\right] \tag{20}$$

subject to

$$\begin{aligned}
A_a &= \begin{cases} M_a - C_a - p_a^h S_a & rr \\ M_a - C_a - p_a^h S_a - p_a^h(1+\kappa_p)H_{a+1} - \kappa P_a & rh \\ M_a - C_a + p_a^h(1-\kappa_s)H_a - \kappa P_a & hr \\ M_a - C_a + p_a^h((1-\kappa_s)H_a - (1+\kappa_p)H_{a+1}) - \kappa P_a & hh' \\ M_a - C_a & hh \end{cases} \\
M_{a+1} &= \begin{cases} (1+r)A_a + Y_{a+1} & A_a \geq 0 \\ (1+r_b)A_a + Y_{a+1} & A_a < 0 \end{cases} \\
W_a &= M_a + p_a^h H_a
\end{aligned}$$

where $M_a$ is the liquid market resources households have at the beginning of age $a$ and $W_a$ is wealth inclusive of income at age $a$.

## 5.2 First Step Estimation

### 5.2.1 The housing market

*The price dynamics of owner-occupied housing*

The fast-rising Norwegian housing prices over the past two decades poses a challenge to our model. At a average growth rate of 2.5% higher than CPI since 1970, the Norwegian *real* housing price has more than tripled as of 2010. It is unlikely that households anticipated such a dramatic rise in the housing price, implying that the realized path of house prices has limited relevance for their life cycle decision making; on the other, households of different cohorts experienced different segments of the realized path of housing price, making it difficult to bring our model in which every household experiences the same path of housing price to the data. For this reason, we assume that $p_a^h = 1$.

*Transaction cost*

In Norway, home buyers must pay a "document tax" of 2.5% of the purchasing price. We therefore set $\kappa_p = 0.025$. The main cost of selling is the honorarium charged by real estate agents. The Financial Supervisory Authority of Norway reports the compensation collected by the main real estate agents in Norway since 2006.[5] For house sales, the average ratio of compensation to transaction value has hovered around 2% from 2006 to 2014. In addition, sellers normally pay for advertisement and sales insurance. Hence, we set $\kappa_s = 0.025$. The opportunity cost parameter $\kappa$ we set equal to fifty percent of the mean monthly income. By using mean rather than individual-specific income, we approximate how high-income individuals are less likely to spend their own time preparing their house for sale.

### 5.2.2 Income Process

*Deterministic component of income*

We consider the following regression

$$\log Y_{ia} = f_i + \sum_{a=27}^{90} \gamma_a D_{ia} + Z_{ia}\beta + y_{ia} \tag{21}$$

where $f_i$ is an individual fixed effect, $D_{ia}$ is an age dummy, $Z_{ia}$ is a vector of observable household characteristics that includes education, family size, nationality and regions, and $y_{ia}$ is the stochastic component of income. The object of interest here is the age profile of income growth rates $\{\gamma_a\}_{a=27}^{90}$, which we will feed into our structural model in the second step estimation through $\Gamma_a = 1 + \gamma_a$ in equation (14).

The top left graph in Figure 3 displays our estimates of average (after-tax) labor income growth rate over the life cycle. There is strong labor income growth when households enter the labor force around 27, implying a sharp increase in the level of income at the beginning of working life. Labor income growth rate declines sharply until age 40 and then falls steadily toward the end of the life cycle.

*Age-varying variance over the life cycle*

The dispersion of income in early stages of life gives rise to different timing of housing purchase. Allowing for age-varying variances of permanent and transitory shocks to income is crucial for our model to match the data. The stochastic component of income follows

$$\Delta y_{ia} = \psi_{ia} + \Delta\xi_{ia} \tag{22}$$

[5] See http://www.finanstilsynet.no/no/Eiendomsmegling/Informasjon/Statistikk/

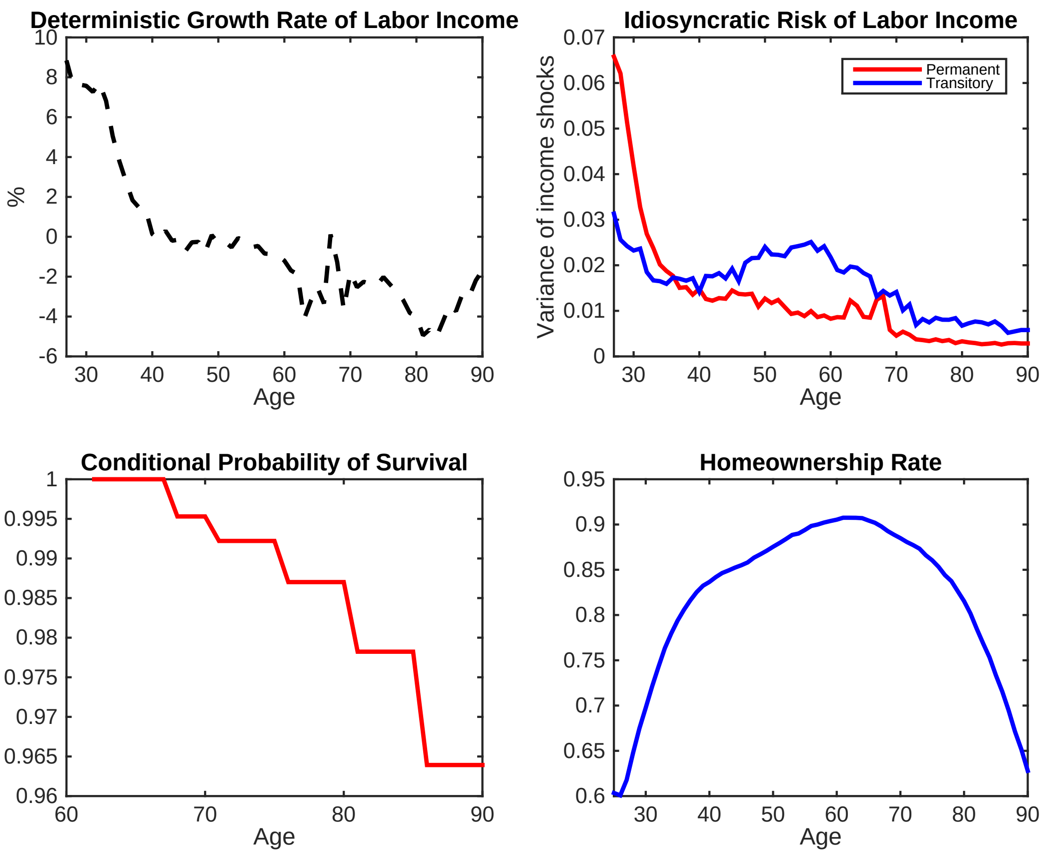


Figure 3: Life Cycle Profiles of Household Labor Income and Demographics

It can be seen that the age-varying variance of permanent shocks are identified by

$$\sigma^2_{\psi,a} = Cov(\Delta y_{ia}, \Delta y_{ia-1} + \Delta y_{ia} + \Delta y_{ia+1}) \tag{23}$$

and the age-varying variance of transitory shocks are identified by

$$\sigma^2_{\xi,a} = -Cov(\Delta y_{ia}, \Delta y_{ia+1}) \tag{24}$$

Four years of data from $a-2$ to $a+1$ are needed to identify the variance of permanent shocks at age $a$ while only three years of data from $a-1$ to $a+1$ are needed for the variance of transitory shocks. In practice, for the estimation of the income process in the model, we need age-varying variances for ages 25 to 90. As the age of households in the data has a wide range from 19 to 111, the age-varying variances are identified.

The top right graph in Figure 3 shows that while variation in the transitory component of labor income remains at the same level, variation in the permanent component of labor income declines sharply during the first decade of working life. At the start of working life, great variation in the levels of permanent income leads to a wide distribution of expected lifetime income. Accordingly, households make their housing choices differently. Close to age 40, the variance of transitory shocks starts to surpass that of permanent shocks and transitory shocks become the dominant source of income uncertainty afterwards.

#### 5.2.3 Demographics

The bottom two graphs in Figure 3 characterize the conditional probability of survival for males after retirement and homeownership rate of households over the life cycle. The conditional probability of survival is averaged over 5 years and thus appears as a step function. Homeownership has a hump-shaped pattern over the life cycle, peaking at the age of 61.

#### 5.2.4 Initial Distribution of Wealth and Income

We divide 26-year-old households into net worth deciles. For each of the 10 net worth groups, we calculate the mean net worth, housing, income and homeownership rate. Table 3 displays the estimation result. In simulating household profiles, we assume that households enter the life cycle with equal probability of belonging to each net worth decile, and within each decile, the share of households who own housing is equal to the homeownership rate in that decile. Households within a certain net worth decile start the life cycle with their decile's mean level of net worth and income, and if they are homeowners, their housing size is equal to the mean level of housing in that decile.

Table 3: Initial Distribution by Net Worth Decile

| Decile | Income | Net Worth | Housing | Homeownership |
|---|---|---|---|---|
| 1 | 2.369 | -9.280 | 11.641 | 0.376 |
| 2 | 1.542 | -2.193 | 11.152 | 0.195 |
| 3 | 1.617 | -0.977 | 11.577 | 0.160 |
| 4 | 1.329 | -0.111 | 11.721 | 0.089 |
| 5 | 1.836 | 0.551 | 11.852 | 0.304 |
| 6 | 2.241 | 3.538 | 12.786 | 0.902 |
| 7 | 1.960 | 7.652 | 13.345 | 0.990 |
| 8 | 1.746 | 11.835 | 15.154 | 0.997 |
| 9 | 1.640 | 16.860 | 18.783 | 0.998 |
| 10 | 1.707 | 33.905 | 31.901 | 0.996 |

All levels are the mean of each net worth decile and in 2005 NOK. Unit is 100,000.

#### 5.2.5 Other parameters

We list other first step estimates of our parameters, including the risk free interest rate, the borrowing rate, housing depreciation rate, and minimum housing in Table 4.

### 5.3 Second Step Estimation

#### 5.3.1 Target in the Data

In our model, there are two kinds of assets: housing $H$ and liquid assets $A$. $A$ captures households' debt when it is negative and financial assets when it is positive. In the data, households often hold debt and financial assets simultaneously. For this reason, we use the age profiles of median net worth, median housing and homeownership rate to estimate the remainder of the parameters in our model. That is, we use the method of simulated moments to estimate our parameters such that the distance between the simulated age profiles and those in the data is the smallest. We do not target debt

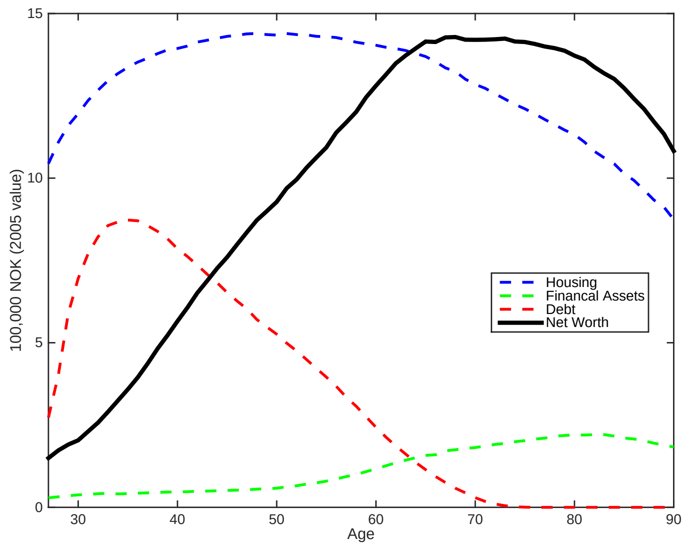


Figure 4: Median Household Balance Sheet Over the Life Cycle

explicitly. Instead, we let the comparison of median debt in the model and in the data serve to test our model's fit.

Figure 4 displays the median profiles of households balance sheet in the data. Median housing is hump-shaped over the life cycle. Median net worth increases until retirement and declines only moderately after retirement. Households hold debt and financial assets simultaneously, but debt is much more pronounced at the beginning of the life cycle.

### 5.3.2 Estimation Results

Table 4 displays our estimation results. All of our preference estimates are in line with the literature. For example, our coefficient of relative risk aversion $\rho$ is less than 2, as is found in Chetty (2006). Our elasticity of substitution $\theta$ is greater than 1 but very close to 1, similar to the result in Piazzesi, Schneider, and Tuzel (2007). As there is no analytical solution to our model, we briefly discuss the identification of the parameters. The average level of median net worth over the life cycle identifies the discount factor $\beta$, as more patient households have more wealth on average. The curvature of the age profile of net worth pins down the coefficient of relative risk aversion $\rho$. Because the $1/\rho$ is the intertemporal elasticity of substitution, a higher $\rho$ implies less wealth accumulation at the beginning of the life cycle and more in the middle. Utility from housing $\zeta$ is nailed down by the average level of median housing and the elasticity of substitution between non-housing and housing consumption $\theta$ is determined by the curvature of the age profile of median housing. Share of non-housing consumption $\alpha$ is largely driven by the homeownership rate while bequest weight $\varphi$ is driven by the level of net worth at the end of the life cycle.

Table 4: Parameter values of the model economy

| | Parameter | Value | Target/Source |
|---|---|---|---|
| **First Step Estimates** | | | |
| **Demographics** | | | |
| Lifespan | $T$ | 90 | |
| Retirement age | $T_r$ | 67 | Norweagian retirement age |
| Conditional probability of survival | $\{p_a^S\}$ | Figure 3 | Statistics Norway |
| **Income process** | | | |
| Permanent income growth rate | $\{\Gamma_t\}$ | Figure 3 | |
| Variance of permanent income | $\{\sigma_{\Psi,t}\}$ | Figure 3 | |
| Variance of transitory income | $\{\sigma_{\Xi,t}\}$ | Figure 3 | |
| **Borrowing** | | | |
| Risk free rate | $r$ | 0.02 | Norges Bank |
| Borrowing rate | $r_b$ | 0.06 | Norges Bank |
| Maximum loan to value ratio | $\mu_V$ | 0.90 | Norges Bank |
| Maximum debt to lifetime income ratio | $\mu_Y$ | 0.25 | |
| **Housing market** | | | |
| Depreciation rate | $\delta$ | 2% | |
| Transaction cost to income ratio | $\kappa$ | 0.04 | Semi-monthly income |
| Transaction cost of purchase | $\kappa_p$ | 0.025 | |
| Transaction cost of sale | $\kappa_p$ | 0.025 | |
| Minimum housing | $\underline{h}$ | 3.5 | Statistics Norway |
| **Second Step Estimates** | | | |
| **Preference** | | | |
| Share of non-housing consumption | $\alpha$ | 0.645 | |
| Discount factor | $\beta$ | 0.937 | |
| Coefficient of relative risk aversion | $\rho$ | 1.503 | |
| Elasticity of substitution | $\theta$ | 1.141 | |
| Utility of owning | $\zeta$ | 0.096 | |
| Bequest weight | $\varphi$ | 3.615 | |

### 5.3.3 Model v.s. Data

Figure 5 shows that our model has the ability to generate similar profiles as in the data under the estimated parameters.

First, the hump-shaped profile of median net worth exists both in the data and in the model. Households accumulate wealth in the first half of the life cycle for precautionary reasons and for retirement. As pension income is low compared to earnings before retirement, households consume out of their wealth after retirement and hence reduce their wealth until the very end of their life. There is one main discrepancy between the model and the data: households deplete their wealth much faster after retirement in the model than in the data. This is mainly for two reasons. In the model, the source of uncertainty after retirement is idiosyncratic income risk and sudden death. Income uncertainty is quite low as most of income is pension. The probability of death is also small at early stages of retirement. Hence, the incentive to save for precautionary reasons is limited. In reality, as households age, health uncertainty rises and households need to save for unexpected medical expenses, which is a source of uncertainty that our model does not capture. In addition, our model only allows for a simple bequest term where bequest and consumption are separable in utility. Non-separable utility is likely to change the curvature of net worth after retirement.

Second, median housing wealth is hump shaped in the data as well as in the model. It is important to note that the median profile of housing wealth is not tracking a single household. Except for the early years in the life cycle, median housing wealth in the model closely tracks the data. In fact, the discrepancy in the early years is likely due to our abstraction of housing price. As Table 3 shows, households in the first few net worth deciles have negative net worth and high levels of housing. It is possible that these households hold on to such big housing when net worth is low because they expect housing price appreciation in the future. In our model, however, without housing price appreciation, it is not optimal for these households to have such big housing when net worth is low.

Third, the purchase of housing is financed by mortgage for a median household in the model. Although we do not directly target debt in the data, our model has reasonably good fit of the life cycle profile of debt. In the model, we make the simplifying assumption that mortgage debt is as liquid as financial assets. As a result, households do not hold mortgage debt and financial assets at the same time. In reality, households do hold both debt and financial assets simultaneously. Thus debt and financial assets in our model should be interpreted as net positions of liquid assets, and this justifies the under-prediction of debt in our model.

Finally, our model over-predicts the homeownership rate by around 10% at most ages. This is likely because we abstract from housing taste and heterogeneity in share of non-housing consumption in our model. In our model, rich households never rent because owning provides more utility than renting per housing unit. In the data, however, some rich households do rent. Each household has the same expenditure share on housing in our model,

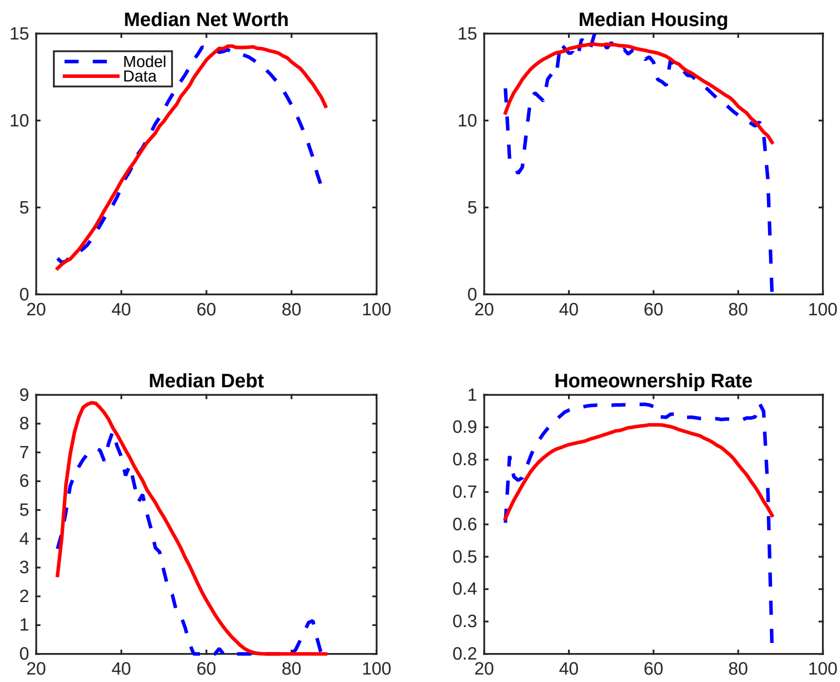


Figure 5: Household Balance Sheet Over the Life Cycle: Model and Data

while in reality, households spend different shares of income on housing.

In terms of the cross-sectional distribution of net worth and leverage, a comparison of Figure 6 generated from simulation and Figure 1 in the data shows that our model captures the heterogeneity in the data reasonably well.

#### 5.3.4 Wealth Effect and the Role of Leverage

*Leverage and the Consumption Response to Wealth Changes*

We next assess the importance of leverage for the marginal propensity to consume. To this end, we repeat the same exercises as we undertook on the actual household data in Section 3.2, on data simulated by our model. Table 5 and 6 present the regression results from the model, and these should be compared to the empirical counterparts in Table 1 and Table 2 respectively. Again, our main parameter of interest is the interaction effect reported in line 5 of each table. We see that the role of leverage in the consumption response to wealth changes is both statistically significant and economically important in the simulated data. In fact, the effect of leverage is even stronger in the model than in the data. This could occur because in the model, leverage is strictly housing leverage, while in the data, debt might also include durable loans. As such, a unit increase of leverage would have

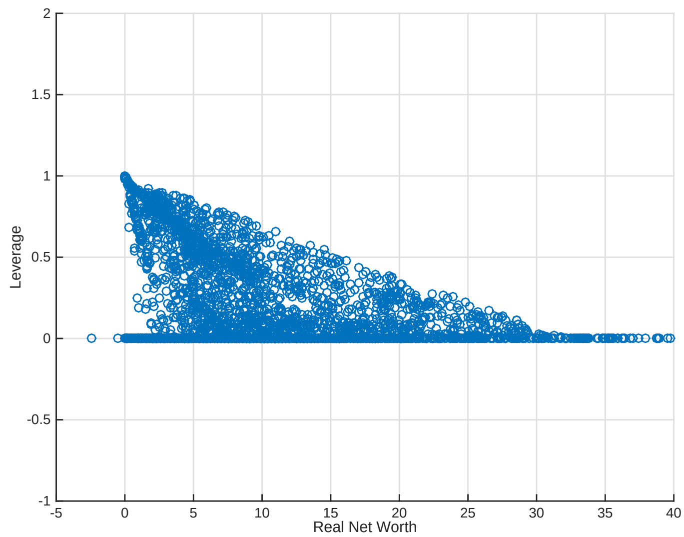


Figure 6: Heterogeneity in Household Leverage and Net Worth in the Simulated Data.

stronger effect on the consumption response to wealth changes in the model than in the data.

To understand the role of leverage in the marginal propensity to consume out of wealth, we divide simulated household profiles into different net worth and leverage groups and calculate the median marginal propensity to consume in each group. Figure 7 reveals graphically the role that leverage plays. The top panel shows that at low levels of wealth, the MPC is high regardless of leverage, which is in line with the concavity of consumption function. At high levels of wealth, however, as leverage increases, the MPC tends to increase. The bottom graph displays the information in the top graph in two dimensions. Each square is a net worth and leverage group. Lighter colors indicate higher MPC. It is clear that colors tend to be lighter at high levels of leverage. Even for relatively rich households with net worth over 500,000 NOK (approximately 80,000 USD), the MPC can be as high as 0.2.

## 6 Conclusion

We provide new micro evidence that the composition of households' balance sheets, in particular their leverage ratio, and not only their overall wealth, matters for their marginal propensity to consume out of wealth changes. Such balance sheet effects are not present in the conventional single-asset buffer stock saving model. We therefore develop and quantify a model to

| | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ |
|---|---|---|---|---|---|---|
| $\Delta W_t$ | 0.245*** | 0.129*** | 0.295*** | 0.180*** | 0.390*** | 0.621*** |
| | (0.002) | (0.003) | (0.002) | (0.003) | (0.053) | (0.053) |
| $W_{t-1}$ | -0.001*** | -0.003*** | 0.008*** | 0.010*** | 0.008*** | 0.010*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| $\Delta W_t \times W_{t-1}$ | -0.004*** | -0.001*** | -0.006*** | 0.000 | -0.002*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| $lev_{t-1}$ | | -0.216*** | | 0.079*** | | 0.102*** |
| | | (0.003) | | (0.004) | | (0.004) |
| $\Delta W_t \times lev_{t-1}$ | | 0.263*** | | 0.291*** | | 0.208*** |
| | | (0.005) | | (0.006) | | (0.007) |
| $\bar{Y}$ | | | -0.066*** | -0.074*** | -0.062*** | -0.070*** |
| | | | (0.000) | (0.001) | (0.001) | (0.001) |
| $\Delta W_t \times \bar{Y}$ | | | 0.014*** | -0.004*** | -0.002*** | -0.012*** |
| | | | (0.000) | (0.001) | (0.001) | (0.001) |
| $age$ | | | | | -0.008*** | -0.027*** |
| | | | | | (0.002) | (0.002) |
| $\Delta W_t \times age$ | | | | | 0.006** | -0.015*** |
| | | | | | (0.003) | (0.003) |
| $age^2$ | | | | | 0.002 | 0.040*** |
| | | | | | (0.004) | (0.004) |
| $\Delta W_t \times age^2$ | | | | | -0.026*** | 0.019*** |
| | | | | | (0.006) | (0.006) |
| $age^3$ | | | | | 0.006** | -0.018*** |
| | | | | | (0.002) | (0.002) |
| $\Delta W_t \times age^3$ | | | | | 0.020*** | -0.009*** |
| | | | | | (0.003) | (0.003) |
| _cons | -0.016*** | 0.054*** | 0.026*** | 0.001 | 0.263*** | 0.522*** |
| | (0.001) | (0.002) | (0.001) | (0.001) | (0.040) | (0.040) |
| adj. $R^2$ | 0.275 | 0.332 | 0.405 | 0.428 | 0.430 | 0.444 |
| N | 89,534 | 89,534 | 89,534 | 89,534 | 89,534 | 89,534 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: The Role of Leverage in the Simulated Data

| | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ | $\Delta C_t$ |
|---|---|---|---|---|---|---|
| $\Delta W_t$ | 0.270*** | 0.110*** | 0.463*** | 0.302*** | 0.478*** | 0.613*** |
| | (0.002) | (0.004) | (0.004) | (0.006) | (0.054) | (0.054) |
| $\frac{W_{t-1}}{Y_{t-1}}$ | 0.019*** | 0.023*** | 0.015*** | 0.014*** | 0.012*** | 0.014*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| $\Delta W_t \times \frac{W_{t-1}}{Y_{t-1}}$ | -0.014*** | 0.005*** | -0.029*** | -0.012*** | -0.010*** | 0.001 |
| | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) | (0.001) |
| $lev_{t-1}$ | | 0.017*** | | -0.017*** | | 0.017*** |
| | | (0.004) | | (0.004) | | (0.004) |
| $\Delta W_t \times lev_{t-1}$ | | 0.268*** | | 0.201*** | | 0.183*** |
| | | (0.005) | | (0.005) | | (0.006) |
| $\bar{Y}$ | | | -0.024*** | -0.025*** | -0.023*** | -0.023*** |
| | | | (0.000) | (0.000) | (0.000) | (0.000) |
| $\Delta W_t \times \bar{Y}$ | | | -0.021*** | -0.015*** | -0.018*** | -0.016*** |
| | | | (0.000) | (0.000) | (0.000) | (0.000) |
| $age$ | | | | | -0.036*** | -0.051*** |
| | | | | | (0.002) | (0.002) |
| $\Delta W_t \times age$ | | | | | 0.003 | -0.017*** |
| | | | | | (0.003) | (0.003) |
| $age^2$ | | | | | 0.060*** | 0.086*** |
| | | | | | (0.004) | (0.004) |
| $\Delta W_t \times age^2$ | | | | | -0.014** | 0.031*** |
| | | | | | (0.006) | (0.006) |
| $age^3$ | | | | | -0.031*** | -0.046*** |
| | | | | | (0.002) | (0.002) |
| $\Delta W_t \times age^3$ | | | | | 0.009*** | -0.021*** |
| | | | | | (0.003) | (0.003) |
| _cons | -0.165*** | -0.182*** | -0.075*** | -0.063*** | 0.602*** | 0.849*** |
| | (0.002) | (0.003) | (0.002) | (0.003) | (0.040) | (0.040) |
| adj. $R^2$ | 0.334 | 0.356 | 0.393 | 0.404 | 0.412 | 0.419 |
| N | 89,534 | 89,534 | 89,534 | 89,534 | 89,534 | 89,534 |

Standard errors in parentheses
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

Table 6: The Role of Leverage in the Simulated Data Controlling for Wealth to Income Ratio

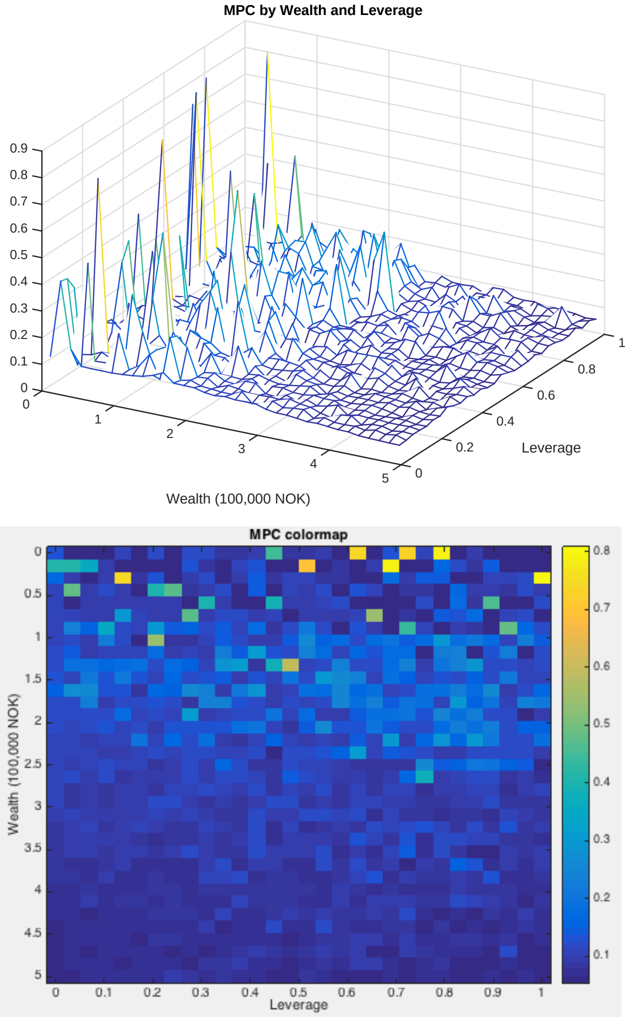


Figure 7: MPC by Wealth and Leverage in the Simulated Data
Wealth is in 2005 NOK and its unit is 100,000.

account for the life cycle profile of households' balance sheets. The capacity of the model to reasonably match housing choice is essential for its capacity to match balance sheet profiles. Our model accounts for the empirical association between leverage and the marginal propensity to consume out of wealth. The key mechanism is that non-convex transaction costs in the housing market, motivate households who are moving up the housing ladder to lever up and buy large houses infrequently. Hence, these recent home buyers will have excessively high housing relative to non-housing consumption, and hence a strong desire to increase their non-housing consumption share. Vice versa, recent homebuyers who have reduced their housing stock, will have low leverage, low housing consumption, and a weak desire to increase their non-housing consumption share. Going forward, we aim to test this specific mechanism in the model more directly, by studying recent homebuyers' marginal propensities to consume.

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# A Details of the Households' Problem

In this section, we describe in detail the problems of households.

At each age $a$, renters decide whether to rent or own next year. The decision, although regarding the future, will affect the value function of renters in the current period. Denote the value functions associated with *deciding* to rent or own next year $V_a^{rr}$ and $V_a^{rh}$ respectively. The value function of renters at age $a$ is

$$V_a^r = \max\left\{V_a^{rr}, V_a^{rh}\right\}$$

Similarly, the value function of homeowners at age $a$ is

$$V_a^h = \max\left\{V_a^{hr}, V_a^{hh}, V_a^{hh'}\right\}$$

where $hr, hh, hh'$ denote the decision of homeowners to rent, stay, and switch to another house next year. We assume that households have bequest motive only after retirement when there is positive probability of death. In particular, the expected value function of households with bequest motives is

$$E_a V_{a+1}^{b,i} = p_{a+1}^S E_a V_{a+1}^i (M_{a+1}, H_{a+1}, P_{a+1}) + (1 - p_{a+1}^S) u^d (W_{a+1}) \qquad i = r, h$$

where

$$u^d(W_{a+1}) = \varphi \frac{W_{a+1}^{1-\sigma}}{1-\sigma}$$

is the utility of bequests and $W_{a+1} = A_a + p_a^h H_{a+1}$ is wealth upon death. $\varphi$ is the relative weight households value bequests and $\sigma$ governs the elasticity of bequests with respect to wealth. For simplicity, we assume that $\sigma = \rho$.

The relationship among different value functions is:

$$\begin{aligned}
V_a^{rr} &= \max_{\hat{C}_a} u(\hat{C}_a) + \beta E_a V_{a+1}^{b,r} \\
V_a^{rh} &= \max_{\hat{C}_a, H_{a+1}} u(\hat{C}_a) + \beta E_a V_{a+1}^{b,h} \\
V_a^{hr} &= \max_{\hat{C}_a} u(\hat{C}_a) + \beta E_a V_{a+1}^{b,r} \\
V_a^{hh} &= \max_{\hat{C}_a} u(\hat{C}_a) + \beta E_a V_{a+1}^{b,h} \\
V_a^{hh'} &= \max_{\hat{C}_a, H_{a+1}} u(\hat{C}_a) + \beta E_a V_{a+1}^{b,h}
\end{aligned}$$

We now characterize the first order conditions and the envelope conditions of each type of movements.

Case I: renter to renter $(rr)$
The intratemporal optimal conditions are:

$$\begin{aligned} \frac{\partial \hat{C}_a}{\partial C_a} = \left(\frac{\alpha \hat{C}_a}{C_a}\right)^{\frac{1}{\theta}} &= \lambda \\ \frac{\partial \hat{C}_t}{\partial S_t} = \left(\frac{(1-\alpha)\hat{C}_a}{S_a}\right)^{\frac{1}{\theta}} &= \lambda p^h_a \end{aligned}$$

Combined with the budget constraint $C_a + p^h_t S_a = p^c_a \hat{C}_a$, we have

$$\begin{aligned} C_a &= \frac{\hat{C}_a}{\left(\alpha^{\frac{1}{\theta}}(1+\frac{1-\alpha}{\alpha}(p^h_a)^{1-\theta})\right)^{\frac{\theta}{\theta-1}}} \\ S_a &= \frac{\frac{1-\alpha}{\alpha}(p^h_a)^{-\theta}\hat{C}_a}{\left(\alpha^{\frac{1}{\theta}}(1+\frac{1-\alpha}{\alpha}(p^h_a)^{1-\theta})\right)^{\frac{\theta}{\theta-1}}} \\ p^c_a &= \left(\alpha + (1-\alpha)(p^h_a)^{1-\theta}\right)^{\frac{1}{1-\theta}} \end{aligned}$$

The intertemporal optimal condition is:

$$u'(\hat{C}_a) = \beta p^c_a \left(p^S_{a+1}(1+r_M)E_a\left[\frac{\partial V^r_{a+1}}{\partial M_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}\right)$$

Envelope condition:

$$\frac{\partial V^{rr}_a}{\partial M_a} = \beta\left(p^S_{a+1}(1+r_M)E_a\left[\frac{\partial V^r_{a+1}}{\partial M_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}\right) = \frac{u'(\hat{C}_a)}{p^c_a}$$

Case II: renter to homeowner $(rh)$
The first order condition with respect to $\hat{C}_a$ is

$$u'(\hat{C}_a) = \beta p^c_a \left(p^S_{a+1}(1+r_M)E_a\left[\frac{\partial V^h_{a+1}}{\partial M_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}\right)$$

The first order condition with respect to $H_{t+1}$ is

$$\beta\left(p^S_{a+1}E_t\left[\frac{\partial V^h_{a+1}}{\partial M_{a+1}}(-(1+\kappa_p)p^h_a(1+r_M)) + \frac{\partial V^h_{a+1}}{\partial H_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}p^h_a(-\kappa_p)\right) = 0$$

Envelope condition:

$$\frac{\partial V^{rh}_a}{\partial M_a} = \frac{u'(\hat{C}_a)}{p^c_a}$$

Case III: homeowner to renter $(hr)$

The first order condition is:

$$u'(\hat{C}_a)\frac{\partial \hat{C}_a}{\partial C_a} = \beta\left(p^S_{a+1}(1+r_M)E_a\left[\frac{\partial V^h_{a+1}}{\partial M_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}\right)$$

The set of envelope conditions is:

$$\begin{aligned}
\frac{\partial V^{hr}_a}{\partial M_a} &= \beta\left(p^S_{a+1}(1+r_M)E_a\left[\frac{\partial V^r_{a+1}}{\partial M_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}\right) \\
\frac{\partial V^{hr}_a}{\partial H_a} &= u'(\hat{C}_a)\frac{\partial \hat{C}_a}{\partial H_a} + \beta p^h_a(1-\kappa_s)\left(p^S_{a+1}(1+r_M)E_a\left[\frac{\partial V^r_{a+1}}{\partial M_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}\right)
\end{aligned}$$

Case IV: homeowner staying $(hh)$
The first order condition is

$$u'(\hat{C}_a)\frac{\partial \hat{C}_a}{\partial C_a} = \beta\left(p^S_{a+1}(1+r_M)E_a\left[\frac{\partial V^h_{a+1}}{\partial M_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}\right)$$

The set of envelope conditions is:

$$\begin{aligned}
\frac{\partial V^{hh}_a}{\partial M_a} &= \beta\left(p^S_{a+1}(1+r_M)E_a\left[\frac{\partial V^h_{a+1}}{\partial M_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}\right) \\
\frac{\partial V^{hh}_a}{\partial H_a} &= u'(\hat{C}_a)\frac{\partial \hat{C}_a}{\partial H_a} + \\
&\quad \beta(1-\delta)\left(p^S_{a+1}E_a\left[\frac{\partial V^h_{a+1}}{\partial H_{a+1}}\right] + (1-p^S_{a+1})p^h_a\varphi W^{-\sigma}_{a+1}\right)
\end{aligned}$$

Case V: homeowner moving $(hh')$
The set of first order conditions are

$$u'(\hat{C}_a)\frac{\partial \hat{C}_a}{\partial C_a} = \beta\left(p^S_{a+1}(1+r_M)E_a\left[\frac{\partial V^h_{a+1}}{\partial M_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}\right)$$

$$\beta\left(p^S_{a+1}E_t\left[\frac{\partial V^h_{a+1}}{\partial M_{a+1}}(-(1+\kappa_p)p^h_a(1+r_M)) + \frac{\partial V^h_{a+1}}{\partial H_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}p^h_a(-\kappa_p)\right) = 0$$

The set of envelope conditions is:

$$\begin{aligned}
\frac{\partial V^{hh'}_a}{\partial M_a} &= \beta\left(p^S_{a+1}(1+r_M)E_a\left[\frac{\partial V^h_{a+1}}{\partial M_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}\right) \\
\frac{\partial V^{hh'}_a}{\partial H_a} &= u'(\hat{C}_a)\frac{\partial \hat{C}_a}{\partial H_a} + \beta p^h_a(1-\kappa_s)\left(p^S_{a+1}(1+r_M)E_a\left[\frac{\partial V^h_{a+1}}{\partial M_{a+1}}\right] + (1-p^S_{a+1})\varphi W^{-\sigma}_{a+1}\right)
\end{aligned}$$

*Consumption and housing in the last possible period*

Households' value function in the last period is:

$$V_T(M_T, H_T, P_T) = u(\hat{C}_T) + \beta u^d(W_{T+1})$$

For renters, the optimal composite consumption follows

$$(\hat{C}_T)^{-\rho} = \beta\varphi p_T^c W_{T+1}^{-\sigma} = \beta\varphi p_T^c (M_T - p_T^c \hat{C}_T)^{-\sigma}$$

and the marginal value of market resources is

$$\frac{\partial V_T^r}{\partial M_T} = \beta\varphi W_{T+1}^{-\sigma} = \frac{u'(\hat{C}_T)}{p_T^c}$$

For homeowners, their optimal non-housing consumption is

$$u'(\hat{C}_T)\frac{\partial \hat{C}_T}{\partial C_T} = \beta\varphi W_{T+1}^{-\sigma} = \beta\varphi(M_T + p_T^h H_T - C_T)^{-\sigma}$$

with marginal value of market resources and housing

$$\frac{\partial V_T^h}{\partial M_T} = u'(\hat{C}_T)\frac{\partial \hat{C}_T}{\partial C_T}$$

$$\frac{\partial V_T^h}{\partial H_T} = u'(\hat{C}_T)\frac{\partial \hat{C}_T}{\partial H_T} + p_T^h u'(\hat{C}_T)\frac{\partial \hat{C}_T}{\partial C_T}$$

For simplicity, we assume that $\sigma = \rho$. Then for renters, their last period composite consumption is

$$\hat{C}_T = \frac{M_T}{(\beta\varphi p_T^c)^{\frac{1}{\rho}} + p_T^c}$$

It can be seen that as $\varphi$ increases, $\hat{C}_T$ decreases.