# Housing, Debt, and the Marginal Propensity to Consume*

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**Abstract**

We analyze how housing and mortgage debt affect households' marginal propensity to consume out of wealth. Using detailed Norwegian registry data, we document that after controlling for wealth, households with higher leverage respond more to wealth changes. Hence, for the purpose of understanding household consumption dynamics, total wealth is an insufficient statistic to summarize household balance sheets. We therefore develop a structural model that can account for mortgage debt over the life cycle and its relation to 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: households who have recently bought houses have high leverage and high marginal propensity to consume. Our estimated model successfully targets the life cycle profiles of household balance sheets in the micro data. As a test of external validity, we show that regressions from data simulated by the model give results consistent with regressions on the actual registry 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 the 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), who provide evidence in this direction, find that during the Great Recession, aggregate consumption responded more to wealth losses in ZIP code areas where leverage was high.

The underpinnings of how and why debt affects consumption dynamics, however, are limited. First, empirically, most of the evidence and the discussion to date has taken place at an aggregate level. Aggregate level data does not establish a direct link between consumption and debt within the same household. It is therefore unclear whether the patterns found actually reflect a link between leverage and consumption responsiveness at the individual level. Moreover, even with individual level data, as in Baker (2015), it is important to be aware that debt might reflect household characteristics rather than constraints. For instance, unobserved household characteristics such as impatience might drive household balance sheets and consumption simultaneously, making it difficult to assess the role of debt despite the use of household level data. Second, on the theoretical side, traditional models of household consumption decisions characterize household balance sheets by total net wealth only, saying nothing about why leverage might matter.

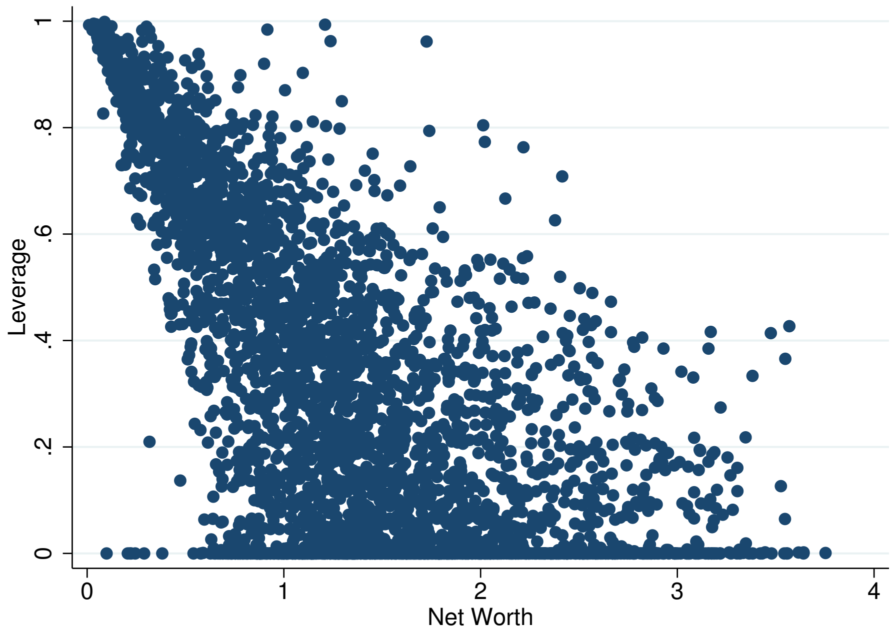
In this paper, we aim to develop a structural model of household behavior that can account for the heterogeneity of household balance sheets in the data and shed light on the relationship between housing leverage and the marginal propensity to consume out of wealth. To this end, we utilize novel Norwegian registry data that contain detailed information on household balance sheets and allow for the construction of imputed consumption. We proceed in two steps. First, we explore if the link between leverage and the marginal propensity to consume out of wealth, which has been documented at the macro level in the U.S. 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 higher consumption response to wealth changes. More importantly, this finding also holds when we control for individual fixed effects. Hence, the pattern does not seem to be primarily driven by heterogeneity in household preferences or other unobserved characteristics. Second, we proceed to our main objective, which is to develop a structural model that can quantitatively account for the typical life cycle profile of household balance sheets. Leverage is endogenously determined in our model, and by construction, households are identical in preferences and their expectations about the future. We compare the model-implied relationship between leverage and consumption and the relationship seen in the data. Such a comparison will be informative about the balance-sheet channels through which debt affects consumption dynamics.

Canonical consumption theory does not distinguish between different asset classes on household balance sheets. The implicit assumption is that only total wealth affects consumption choice. Debt, in other words, matters only insofar as it affects net worth. In the data, however, there is substantial heterogeneity in household balance sheets. Figure 1 compares leverage and net worth in Norwegian households between 2005 and 2011. For any given level of net worth, there is a great deal of variation in leverage. This is what allows us to estimate the role of leverage, over and beyond its relation with wealth. To understand the role of debt and evaluate its policy implications, we must move beyond the benchmark single-asset model of consumption towards a model that incorporates a richer balance sheet. We develop a model that differentiates between the three main asset classes held by Norwegian households: housing, debt, and other financial assets. We then estimate our model to capture the life cycle profile of balance sheets in the data.

We argue that housing decisions are key to accounting for the typical life cycle profile of household balance sheets that are seen in the data. Before making discrete house purchases that are largely financed by debt, households typically accumulate financial assets over time. Indeed, they tend to re-balance their portfolio between housing and other assets very infrequently. For this reason, our model treats housing decisions in some detail, and it distinguishes homeownership from renting. Households are subject to uninsurable idiosyncratic labor income risks and borrowing constraints. In each period, renters allocate intratemporal consumption between non-housing consumption and housing services (rental payments); homeowners make choices about non-housing consumption while enjoying the service flow of their current house. Households also make decisions about next period's homeownership status. For instance, renters can decide to become homeowners next period and choose the house size that is optimal for them. However, there are transaction costs associated with buying and selling houses.

The existence of transactions costs makes homeowners move infrequently. In addition, households must hold some equity on their house. As a result, housing wealth, at least the fraction against which homeowners cannot borrow, is less liquid than financial wealth. While a house purchase almost does not change a household's total wealth, it does imply a shift in the liquidity of its balance sheets. Buyers who are expanding their housing stock move closer to their borrowing constraint because part of their liquid wealth has

Figure 1: Heterogeneity in Household Leverage and Net Worth




*Notes*: This figure presents a 0.2% random sample of the household data we use in this paper. Each dot represents a household-year observation. Leverage in this context is defined as the ratio of debt to housing value. Net worth is in millions of Norwegian Krones, indexed to the 2000 price level. The nominal exchange rate between Norwegian Krones and US dollars during our sample period is about 6 NOK per 1 USD.

been transformed into housing. Most home buyers finance their house purchase primarily with debt, and so homeowners who have recently expanded their housing stock have high leverage. The combination of proximity to the borrowing constraint and high transaction costs raises these households' marginal propensity to consume out of wealth. In fact, households' MPC does not monotonically decrease in wealth: a recent home buyer has a higher MPC than she had immediately before buying the house, even though there is virtually no change in her total wealth. Households that own larger houses and have more debt tend to have higher MPC than those that have smaller balance sheets. Leverage, therefore, measures liquidity, or equivalently the proximity to the borrowing constraint in the presence of housing, which is an aspect that total wealth would not capture. Thus housing decisions are 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 out of wealth is related to leverage.

The rest of this paper is organized as follows. Section 2 reviews related literature. Section 3 describes the Norwegian registry data and explores the empirical relationship between leverage and the consumption response to wealth changes. In section 4, we develop a full-fledged consumption-saving model with housing, debt, and financial assets. Section 5 shows that a calibrated version of this model is able to capture the typical composition of a median household's balance sheet over the life cycle and generates a reasonable marginal propensity to consume out of wealth. Section 6 discusses the policy implications of the model and Section 7 concludes.

## 2 Relation to the Literature

Our paper contributes 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 would imply. In an empirical analysis of household level data, Dynan (2012) find that compared to other homeowners, highly leveraged homeowners had larger declines in consumption between 2007 and 2009. Mian, Rao, and Sufi (2013), who examine ZIP code level auto sales data, find that the consumption response to housing wealth changes was larger in zip codes with poorer and more levered households. Our empirical analysis contributes to this literature by using novel Norwegian registry data at the household level. We focus on the period between 2005 and 2011 because our housing wealth measure is the most accurate for this period. While the U.S. and Europe were greatly hit by the Great Recession, the impact on Norway during this period was relatively small. Thus, the role of leverage that we highlight is not limited to recessions. Most of the theoretical literature that examines 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 that have higher leverage respond more to wealth changes, and thus when wealth declines they would optimally choose to de-lever more than others.

Our paper is closely related to an old but recently revived literature on excess sensitivity with respect to transitory shocks. Mounting evidence indicates that the marginal propensity to consume out of transitory shocks is well above zero—a finding that contrasts with the implication of off-the-shelf representative agent models. 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. In their model, however, among households that have the same preferences, it is essentially the poor households who exhibit the largest MPCs. As our model shows, even for households that have 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 resembles theirs. But in our model households prefer home ownership because it provides more utility than renting. Thus our results do not rely on excess returns on housing. Moreover, in Kaplan and Violante (2014), there are no explicit transitory shocks, but as emphasized in Deaton (1991), the presence of transitory shocks can to a great extent affect wealth accumulation. In this paper we explicitly consider transitory shocks. In our model, transitory shocks give rise to a dispersion of income and wealth for households with the same permanent income at the same stage of their life cycle. The dispersion is important for the timing of housing transactions. Without transitory shocks, households tend to move together, creating discrete jumps in homeownership rates.

The third strand of literature to which our paper contributes examines life cycle choices. Gourinchas and Parker (2002) and Cagetti (2003) estimate the structural preference parameters of life cycle models of consumption and saving. Fernandez-Villaverde and Krueger (2011) study durable and nondurable consumption over the life cycle. Yang (2009) accounts for housing and nonhousing consumption profiles over the life cycle. In contrast to these papers, which are centered on consumption and saving patterns over the life cycle, we focus on the heterogeneity in consumption response to wealth changes and its implications. To estimate the structural parameters of our model, we match the life cycle profiles of housing and net worth of a median household and homeownership rates in our data. We show that the estimated model implies reasonable MPCs and a similar propagating role of leverage that resembles what is seen in the data.

To solve our model, we employ a variant of the endogenous grid point method in Carroll (2006). In contrast to the common practice of using value function iterations to solve dynamic stochastic optimization models, the endogenous grid point method solves the model quickly and accurately and allows us to estimate the structural model within a reasonable amount of time. Because it involves transaction costs, discrete and continuous choices, and occasionally binding constraints, our modified version of endogenous grid point method contains elements adopted from Iskhakov, Jørgensen, Rust, and Schjerning (2014) and Hintermaier and Koeniger (2010).

# 3 The Role of Leverage

This section explores the empirical relationship between leverage and consumption dynamics at the household level. This issue cannot be answered without full knowledge of the structure and the dynamics of household balance sheets, which makes the Norwegian registry data ideal for the purpose of our study. We first describe the data and then move on to the empirical analysis.

## 3.1 The Norwegian Registry Data

The Norwegian administrative micro-data on income and wealth reports wealth every year, and not, as in the PSID, every 4 years. Thus, consumption can be estimated as the residual of disposable income and savings without having to estimate wealth as well. Browning and Leth-Petersen (2003) and Koijen, Van Nieuwerburgh, and Vestman (2014) take this approach to impute consumption from the Danish and Swedish registry data, respectively, and they conclude that the results are promising. Following a similar approach, Fagereng and Halvorsen (2015) impute consumption for Norwegian households from 1993 to 2011. We base our study on their consumption measures. In what follows, we provide a brief description of the imputation procedure. A more detailed exposition of the procedure can be found in Fagereng and Halvorsen (2015).

The imputation is based on the household budget constraint, which states that consumption of household $i$ in period $t$ is income minus savings:

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

Here the second line first separates between[1] 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 thereafter it separates between savings in terms of financial asset accumulation $\Delta a_{it}$ and savings in terms of debt changes $\Delta d_{it}$. 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 household specific interest rate on debt between $t$ and $t-1$,

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

and $r^f_{it}$ is the household specific return on the asset portfolio held between $t$ and $t-1$. Imputed rents on real assets, $\left(r^r_{it}a^r_{it-1}\right)$, are included as part of income, but we do not include 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 consist of bank accounts, stocks (listed and non-listed), bonds, mutual funds, money market 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. All amounts are denoted in real terms (with base year 2000), where the deflator is the Norwegian consumer price index.

Appendix A provides further information about the administrative tax records in Norway and the imputation of housing values. For the empirical exercises in this paper, we use a 20% sample of the Norwegian registry data from 2005 to 2011. We focus on this time period because before 2005, individual level house values were substantially underreported. Since 2005, Statistics Norway has estimated house values on the basis of hedonic price regressions, using characteristics such as location, size and number of balconies. We drop observations in the top and the bottom 5% of wealth and the wealth-to-income ratio because the consumption behavior of the extremely wealthy or indebted households is not our primary interest. We also drop those who have non-listed stocks because the imputation of their stock value and hence their consumption is more prone to error. We further drop observations whose housing leverage is greater than 3 because most of their debt probably is related to business or their housing value is undervalued. In the end, we have about 2 million observations.

### 3.2 Housing Leverage and Consumption

We now use the Norwegian micro data to explore whether leverage, defined as the debt-to-housing ratio, is related to household consumption response to wealth changes. Our investigation is closely related to that of Mian, Rao, and Sufi (2013), who find that at the ZIP code level, the marginal propensity to consume out of housing wealth changes (MPC hereafter) differed significantly by leverage level during the Great Recession. We address two questions. First, does the relationship between leverage and consumption responses to wealth changes hold at a disaggregated household level in an environment that was more tranquil than the one Mian, Rao, and Sufi (2013) explored? Second, how does the relationship between leverage and the MPC move from the micro level to the macro level? In other words, we study how aggregation affects the role of leverage.

As a starting point, consider the consumption function in standard buffer-stock saving models with only one asset, such as the type surveyed by Heathcote, Storesletten, and Violante (2009). In these models, labor income uncertainty gives households a precautionary motive. Consumption $C_t$ is an increasing and concave function of wealth $W_t$ (inclusive of current labor income). Wealth, $W_t$, is the state variable that summarizes a household's balance sheet at time $t$, and it influences the consumption response to wealth changes in the next period. In the presence of permanent income shocks, it is the ratio of wealth to permanent income that summarizes household balance sheet because it measures the wealthiness of households in terms of their lifetime income.

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 whether leverage is related to the marginal propensity to consume out of wealth changes. To this end, we estimate

$$\begin{aligned} \Delta C_{it} &= \beta_0 + \beta_1 \Delta W_{it} + \beta_2 W_{it-1} + \beta_3 \Delta W_{it} \times W_{it-1} \\ &\quad + \beta_4 lev_{it-1} + \beta_5 \Delta W_{it} \times lev_{it-1} \end{aligned} \tag{2}$$

From the standard buffer-stock saving models, we expect that $\beta_3 < 0$ because of the concavity of the consumption function (Carroll and Kimball (1996)). We would also expect that $\beta_5$ is insignificant, as wealth summarizes household balance sheets and there is essentially no role for leverage. Our key parameter of interest in Equation (2) is $\beta_5$. After controlling for household wealth, does the composition of a household balance sheets affect its consumption response to wealth changes ($\beta_5 \neq 0$)?

Table 1a shows that leverage does play such a role. Column (1) of Table 1a 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 with what a standard buffer-stock saving model would predict. 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. This coefficient is both highly statistically significant and economically important. For instance, consider a household that recently bought its first house, which was largely financed by debt as is typical of first-time home buyers. Its wealth level has barely

Table 1a: Housing Leverage and Consumption Response to Wealth Changes

| Dep.Var: | $\Delta C_t$ | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $\Delta W_t$ | 0.595*** | 0.445*** | 0.531*** | · |
| | (0.002) | (0.002) | (0.106) | |
| $W_{t-1}$ | -0.012*** | -0.060*** | -0.096*** | 0.121*** |
| | (0.000) | (0.000) | (0.001) | (0.004) |
| $\Delta W_t \times W_{t-1}$ | -0.015*** | 0.003*** | 0.008*** | 0.064*** |
| | (0.001) | (0.001) | (0.001) | (0.007) |
| $lev_{t-1}$ | | -0.194*** | -0.337*** | -0.747*** |
| | | (0.001) | (0.001) | (0.008) |
| $\Delta W_t \times lev_{t-1}$ | | 0.197*** | 0.226*** | 0.375*** |
| | | (0.002) | (0.002) | (0.022) |
| Year# | X | X | X | X |
| $\bar{Y}$# | | | X | X |
| CHAR# | | | X | X |
| FEIS | | | | X |
| adj. $R^2$ | 0.281 | 0.309 | 0.346 | 0.231 |
| N | 1,346,844 | 1,346,844 | 1,346,264 | 1,191,995 |

*Notes.* This table presents coefficients from regressions that relate the change in household consumption to the change in household wealth at an annual frequency between 2006 and 2011. All regressions are at the household level. Δ indicates change in millions of Norwegian Krones that are indexed to the 2000 price level. Leverage is defined as debt over housing value. # signifies that both the level of the term and its interaction with $\Delta W_t$ are included. Year includes year dummies. $\bar{Y}$ is average household income in the sample. CHAR includes terms of household characteristics. FEIS is fixed effect in the slope of $\Delta W_t$. Thus, for column (4), we omit the coefficient for $\Delta W_t$ and report within-household adjusted $R^2$. Throughout, standard errors are in parentheses. *** indicates that coefficients are statistically different from 0 at the 1% confidence level.

changed but its balance sheet composition has changed 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 then increase by almost 20 cents.

Column (3) adds to the regression income and household characteristics as well as their interaction terms with the change in wealth.[2] We want to examine the possibility that leverage is picking up either the effect of income expectations or observable household characteristics. It is possible that households that expect higher a future income want to take on more leverage, and because their current wealth is low relative to lifetime income, they have a higher marginal propensity to consume out of wealth changes. In column (3), average income serves as a proxy for households' permanent income. Age polynomials, which are included in household characteristics, together with average income captures the deterministic profile of household income over the life cycle and thus serve as a proxy for households' income expectations. The estimates in column (3) indicate that expected income is not driving our results, nor is any other observable household characteristics. The coefficient on the interaction term between leverage and wealth changes—$\beta_5$ in equation (2)—increases slightly and remains highly significant.

In column (4), we test whether the role of leverage is mainly driven by unobserved household characteristics. Parker (2015) finds that the propensity to consume is a persistent trait of households and that this trait is highly related to impatience. This poses a challenge to the interpretation of our results because impatient households probably are more indebted than patient households and hence our leverage term could reflect this unobserved heterogeneity in preferences. We therefore add a fixed effect in the slope of wealth changes in order to capture the persistence in households' propensity to consume.[3] In the results, reported in column (4), we see that the role of leverage does not disappear when we control for these fixed effects. Hence it does not seem that the leverage effect is driven by heterogeneity in impatience. In fact, the estimate of $\beta_5$ in equation (2) is *larger* than what is estimated in columns (1)-(3)—a point we will come back to in our aggregation results.

Table 1b presents the results of equation (2) wherein the level of wealth is replaced by the wealth-to-income ratio. We see that the two sets of estimates

[2] Household characteristics include age polynomials up to the third order, family size, number of children, education status, marital status, family type, and counties where households reside.

[3] That is , we allow $\beta_0$ and $\beta_1$ in equation (2) to be different for different households. We use FEIS to denote a fixed effect in slopes in regression tables. Because house price appreciated in Norway during the sample period, variation in household leverage allows us to identify $\beta_5$ even when there is a fixed effect in slopes.

are quite similar. In particular, the estimates of $\beta_5$ are are comparable to those in Table 1a.

The richness of the micro-level data allows us to aggregate households to the municipality and county level. This is interesting for two reasons. First, aggregation is likely to average out heterogeneity in household preferences, and consequently it will help us evaluate whether leverage plays a role because of the true balance sheet effect or because of preference heterogeneity.[4] Second, by aggregating the data we can gauge the extent to which estimates at the macro level, like those in Mian, Rao, and Sufi (2013), are likely to capture effects present at the micro level.

Column (3) in Table 2a shows that in our setting aggregation at the municipality level does not reduce the role of leverage. At the macro level, leverage is even more strongly associated with the consumption response to wealth changes. Column (4) shows that at the county level the point estimate of $\beta_5$ is about the same as that at the municipality level, but it is no longer statistically significant. Because there are only 19 counties in the data, the lack of significance is not surprising. Columns (1) and (2) in Table 2a restate some of the results that are reported in Table 1a. Interestingly, columns (2) and (3) show that adding fixed effects in slope at the household level yields an estimate of $\beta_5$ that is similar to that at the municipality level—both of the estimates are larger than the micro estimate without fixed effects in column (1). It is possible that at the household level the role of leverage is mitigated by differences in household preferences or by the nonlinearity of the relationship between leverage and the marginal propensity to consume. In Table 2b, where we replace the level of wealth with the wealth-to-income ratio, the results resemble those of Table 2a.

Our results at different aggregation levels and the fixed effects regressions indicate that the role of leverage is not due simply to preference heterogeneity. Moreover, the influence of leverage, over and beyond its correlation with wealth and possibly with preferences, cannot be explained within single-asset buffer-stock models of household consumption. In the remainder of this paper we develop a structural model that can account for the relationship between leverage and consumption dynamics.

[4] On the other hand, if consumption response to wealth changes is inherently related to leverage in a nonlinear way, aggregation is likely to exaggerate or mitigate the role of leverage.

Table 1b: Housing Leverage and Consumption Response to Wealth Changes

| Dep.Var: | $\Delta C_t$ | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $\Delta W_t$ | 0.659*** | 0.521*** | 0.804*** | . |
| | (0.001) | (0.002) | (0.107) | |
| $\frac{W_{t-1}}{Y_{t-1}}$ | 0.001*** | -0.013*** | -0.012*** | 0.006*** |
| | (0.000) | (0.000) | (0.000) | (0.001) |
| $\Delta W_t \times \frac{W_{t-1}}{Y_{t-1}}$ | -0.017*** | -0.010*** | -0.010*** | -0.002 |
| | (0.000) | (0.000) | (0.000) | (0.002) |
| $lev_{t-1}$ | | -0.201*** | -0.253*** | -0.864*** |
| | | (0.001) | (0.001) | (0.007) |
| $\Delta W_t \times lev_{t-1}$ | | 0.167*** | 0.206*** | 0.299*** |
| | | (0.002) | (0.002) | (0.021) |
| Year# | X | X | X | X |
| $\bar{Y}$# | | | X | X |
| CHAR# | | | X | X |
| FEIS | | | | X |
| adj. $R^2$ | 0.283 | 0.306 | 0.335 | 0.224 |
| N | 1,346,844 | 1,346,844 | 1,346,264 | 1,191,995 |

*Notes*. This table presents coefficients from regressions that relate the change in household consumption to the change in household wealth at an annual frequency between 2006 and 2011. All regressions are at the household level. $\Delta$ indicates change in millions of Norwegian Krones that are indexed to the 2000 price level. Leverage is defined as debt over housing value. # signifies that both the level of the term and its interaction with $\Delta W_t$ are included. Year includes year dummies. $\bar{Y}$ is average household income in the sample. CHAR includes terms of household characteristics. FEIS is fixed effect in the slope of $\Delta W_t$. Thus, for column (4), we omit the coefficient for $\Delta W_t$ and report within-household adjusted $R^2$. Throughout, standard errors are in parentheses. *** indicates that coefficients are statistically different from 0 at the 1% confidence level.

Table 2a: The Role of Housing Leverage at Different Aggregation Levels

| Dep.Var: | $\Delta C_t$ | | | |
|---|---|---|---|---|
| Agg. Level: | Household | Household | Municipality | County |
| | (1) | (2) | (3) | (4) |
| $\Delta W_t \times lev_{t-1}$ | 0.226*** | 0.375*** | 0.348*** | 0.390 |
| | (0.002) | (0.022) | (0.054) | (0.595) |
| Baseline $W_{t-1}$ | X | X | X | X |
| Year# | X | X | X | X |
| Age# | X | X | X | X |
| CHAR# | X | X | | |
| FEIS | | X | | |
| adj. $R^2$ | 0.291 | 0.231 | 0.939 | 0.950 |
| N | 1,346,844 | 1,191,995 | 2,147 | 95 |

*Notes.* This table presents coefficients from regressions that relate the change in household consumption to the change in household wealth at an annual frequency between 2006 and 2011. Regressions in columns (1) and (2) are at the household level, and regressions in columns (3) and (4) are at the municipality and county levels, respectively. $\Delta$ indicates change in millions of Norwegian Krones that are indexed to the 2000 price level. Leverage is defined as debt over housing value. # signifies that both the level of the term and its interaction with $\Delta W_t$ are included. Year includes year dummies. CHAR includes terms of household characteristics. FEIS is fixed effect in the slope of $\Delta W_t$. $\bar{Y}$ is average household income in the sample. Baseline $W_{t-1}$ refers to four terms involving $\Delta W_t$, $W_{t-1}$, $\Delta W_t \times W_{t-1}$, and $lev_{t-1}$. Age for columns (3) and (4) are the average age of households at the time and includes interaction with $\Delta W_t$. Throughout, standard errors are in parentheses. *** indicates that coefficients are statistically different from 0 at the 1% confidence level.

Table 2b: The Role of Housing Leverage at Different Aggregation Levels

| Dep.Var: | $\Delta C_t$ | | | |
|---|---|---|---|---|
| Agg. Level: | Household | Household | Municipality | County |
| | (1) | (2) | (3) | (4) |
| $\Delta W_t \times lev_{t-1}$ | 0.206*** | 0.299*** | 0.306*** | 0.667 |
| | (0.002) | (0.021) | (0.083) | (0.597) |
| Baseline $\frac{W_{t-1}}{Y_{t-1}}$ | X | X | X | X |
| Year# | X | X | X | X |
| Age# | X | X | X | X |
| CHAR# | X | X | | |
| FEIS | | X | | |
| adj. $R^2$ | 0.335 | 0.224 | 0.936 | 0.949 |
| N | 1,346,264 | 1,191,995 | 2,147 | 95 |

*Notes.* This table presents coefficients from regressions that relate the change in household consumption to the change in household wealth at an annual frequency between 2006 and 2011. Regressions in columns (1) and (2) are at the household level, and regressions in columns (3) and (4) are at the municipality and county levels, respectively. $\Delta$ indicates change in millions of Norwegian Krones that are indexed to the 2000 price level. Leverage is defined as debt over housing value. # signifies that both the level of the term and its interaction with $\Delta W_t$ are included. Year includes year dummies. CHAR includes terms of household characteristics. FEIS is fixed effect in the slope of $\Delta W_t$. $\bar{Y}$ is average household income in the sample. Baseline $W_{t-1}/Y_{t-1}$ refers to four terms involving $\Delta W_t$, $W_{t-1}/Y_{t-1}$, $\Delta W_t \times W_{t-1}/Y_{t-1}$, and $lev_{t-1}$. Age for columns (3) and (4) are the average age of households at the time. Throughout, standard errors are in parentheses. *** indicates that coefficients are statistically different from 0 at the 1% confidence level.

# 4 Model

In this section, we develop a full-fledged consumption-saving life-cycle model with housing, debt, and financial assets. Housing leverage naturally emerges in our model and hence enables us to later explore its relation with the consumption response to wealth changes. Although our model is similar to that of Kaplan and Violante (2014), it differs in two main aspects. First, in our model, households buy housing because it is a consumption good and not because it provides a higher return than the risk free rate. Second, in our model debt consists primarily of mortgages and many households are levered. In Kaplan and Violante's (2014) model, debt is unsecured borrowing, and because the interest rate on this debt is prohibitive, in practice there is little leverage.

We then estimate our model in two steps. First, we estimate one set of the model's parameters externally. Second, we use the simulated method of moments to estimate the remaining parameters that govern household preferences, such that our simulated median profiles of housing, debt and financial asset as well as homeownership rates are as close to the data as possible.

## 4.1 A Model of Housing, Debt, and Financial Assets

The economy consists of a continuum of households. Households begin their life cycle at age $a_0$ and exit at age $T$ with certainty.[5] At each age $a$, there is risk of death and the conditional probability of survival is $p_a^S$. Households derive utility from consumption and bequest.

Households enjoy a bundle of housing and non-housing consumption, with a constant elasticity of substitution between the two:

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

Here $\theta$ is the elasticity of substitution, $C_a$ is non-housing expenditure, and $S_a = \zeta H_a$ is the service flow from housing. $H_a$ is the stock of owner-occupied housing.

The weight on non-housing expenditure in the consumption bundle, $\alpha_a$, depends on the household composition and thus varies with age. Specifically, we assume

$$\alpha_a \propto \alpha \exp\{f_a N_a^{Adult} + f_c N_a^{Children}\}$$

with the normalization that $\alpha_{a_0} = \alpha$, where $\alpha$ is the initial weight on non-housing expenditure. $N_a^{Adult}$ and $N_a^{Children}$ are the number of adults and the

[5] In practice, we choose $a_0 = 27$ and $T = 90$ for the life cycle.

number of children in the household at age $a$, and $f_a$ and $f_c$ are parameters that capture their impact on the weight on non-housing consumption. This specification is chosen to capture how household size and household composition affect consumption over the life cycle. Because household composition varies, the flexible formulation of this specification allows us to estimate the equivalence scale in order to capture consumption per capita.[6][7]

Households have a constant relative risk aversion (CRRA) utility function over consumption

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

When there is positive probability of death, households derive additional utility from leaving a bequest. We assume that the utility from bequests follows

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

where $W_{a+1}$ is wealth upon death and $\varphi$ is the relative weight with which households value bequests. Each household therefore maximizes its expected discounted utility from consumption and bequest

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

where $\beta$ is the discount factor.

*Income Process*

Households have a permanent-transitory type of income process:

$$\begin{aligned} Y_a &= P_a \Xi_a \\ P_a &= \Gamma_a P_{a-1} \Psi_a\,, \end{aligned} \tag{3}$$

where $Y_a$ is 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 common to all households, and $\Psi_a$ is the

[6]As emphasized in Attanasio, Banks, Meghir, and Weber (1999) and Cagetti (2003), allowing demographics to affect household preferences can generate consumption profiles over age similar to those observed in household data.

[7]For instance, Kaplan (2012) lists five equivalence scales that are used in different contexts. We do not take a stand on which one is the better; instead we estimate the influence of household composition on consumption choice.

permanent shock to income. We assume that transitory and permanent shocks are log-normally distributed

$$\begin{aligned}\xi_a &= \log \Xi_a \sim N(-\frac{\sigma^2_{\xi,a}}{2}, \sigma^2_{\xi,a}) \\ \psi_a &= \log \Psi_a \sim N(-\frac{\sigma^2_{\psi,a}}{2}, \sigma^2_{\psi,a})\,,\end{aligned}$$

where $\sigma^2_{\xi,a}$ and $\sigma^2_{\xi,a}$ are age-varying variances of transitory and permanent shocks, respectively. Under these assumptions, $E(\Xi_a) = E(\Psi_a) = 1$.

*Renters and Homeowners*

Households can be renters or homeowners. They also make decisions about moving and house size. Renters can decide to remain renters or become homeowners in the next period. Homeowners can become renters, stay in their current house, or buy another house to move into in the next period. For transparency, we denote the five possible types of movements between renters and homeowners as $rr$, $rh$, $hr$, $hh$ and $hh'$ respectively. We assume that moving out of or into rented housing has no cost and that changes in owner-occupied housing imply a transaction cost. In particular, we assume that there are proportional transaction costs $\kappa_p$ and $\kappa_s$ that accompany housing purchase and sale.

*Budget Constraints*

When renters decide to remain renters for one more period, they allocate consumption between non-housing expenditure $C_a$ and housing service $S_a$ in the current period. Their intertemporal budget constraint is

$$A_a = M_a - C_a - S_a\,,$$

where $M_a$ is total market resources available at age $a$ and $A_a$ is the end-of-period assets. If renters decide to become homeowners, they must finance their housing purchase in addition to their current consumption:

$$A_a = M_a - C_a - S_a - (1 + \kappa_p)H_{a+1}\,.$$

Homeowners, in contrast, enjoy their housing, and if they do not move, all of their expenditure at the age $a$ is non-housing expenditure. Moving introduces housing transactions to homeowners' budget constraint. For instance, a homeowner who decides to become a renter ($hr$) sells her house, but during the current period she still enjoys the service flow from her current house:

$$A_a = M_a + (1 - \kappa_s)H_{a+1} - C_a\,.$$

*Borrowing*

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

$$A_a \geq -\mu_U P_a \,.$$

Second, there is a loan to value constraint

$$A_a \geq -\mu_V p_a^h H_{a+1} \,.$$

Third, there is a loan to income constraint

$$A_a \geq -\mu_Y PV_a \,,$$

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 discounted at the borrowing rate. With respect to a household's end-of-period assets, the loan to value constraint requires that debt cannot exceed a certain fraction of its current housing value, while the loan to income constraint requires that debt not exceed a certain fraction of the household's expected future income.

*Households' Optimization Problem*

Taking all the aforementioned details into account, we can express the households' optimization problem as:

$$\max_{\{C_a, S_a, H_a\}} u(\tilde{C}_{a_0}) + E_{a_0} \left[ \sum_{a=a_0+1}^{T} \beta^{a-a_0} \left( p_a^S u(\tilde{C}_a) + (1-p_a^S) u^b(W_a) \right) \right]$$

subject to

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

Here $M_a$ is the liquid market resources households have at the beginning of age $a$ and $W_a$ is wealth inclusive of income at age $a$. The only distinction between debt and financial assets in our model is their interest rate. When end-of-period assets, $A_a$, are negative, households are in debt; when $A_a$ is positive, households hold financial assets. Both debt and financial assets are liquid in the sense that households can run them up or down without cost, subject to the constraints.

### 4.2 First Step Estimation

*Transaction Cost*

In Norway, home buyers must pay a "document tax" that is 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.[8] Between 2006 and 2014, the average ratio of compensation to transaction value for house sales hovered around 2%. In addition, sellers normally pay for advertisement and sales insurance. Hence, we set $\kappa_s = 0.025$.[9]

*Deterministic Component of Income*

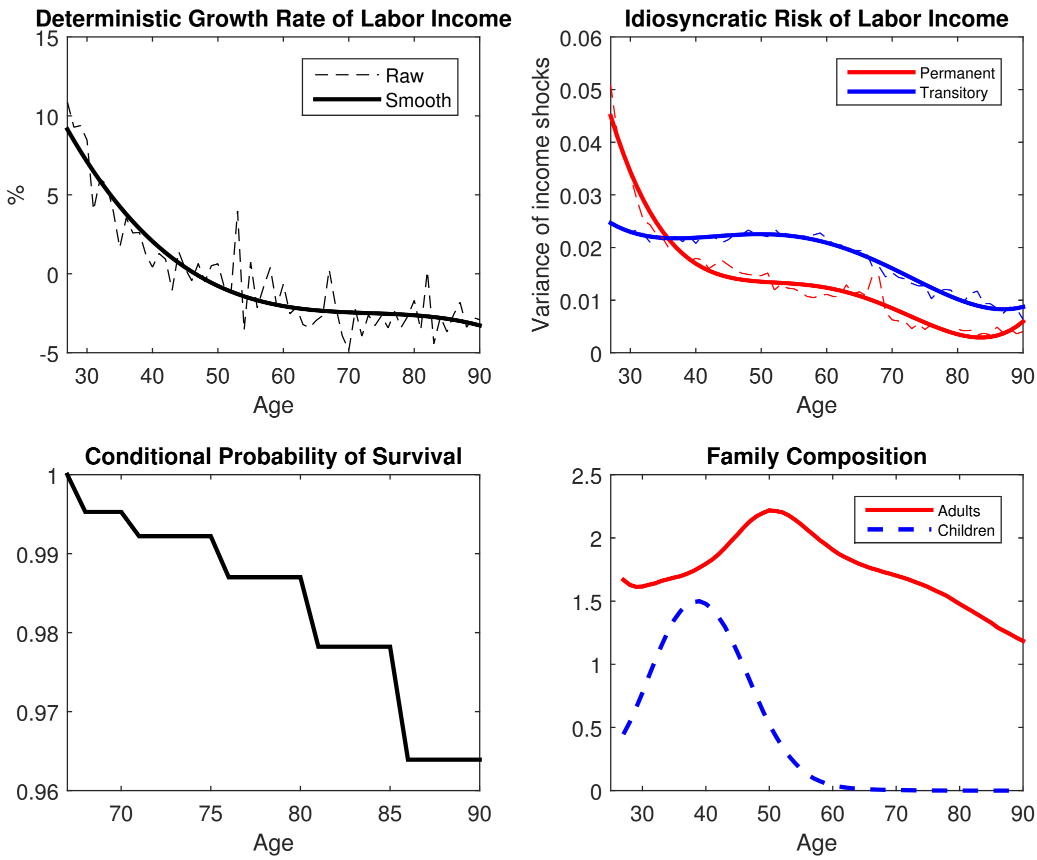
It is well known that because of collinearity, age, year and cohort effects on income growth cannot be separately identified without making further assumptions (see for example Deaton and Paxson (1994)). Our data only span 7 years—not long enough to cover several business cycles. Thus we cannot assume that year effects are zero on average. Instead of making strong assumptions about the pattern of cohort effects, we choose the growth rates of mean after-tax income over age in the data as the deterministic growth rate of permanent income, $\{\gamma_a\}_{a=28}^{90}$. Using a third-order polynomial we then obtain smoothed growth rates, which in the second step estimation we feed into our structural model through $\Gamma_a = 1 + \gamma_a$ in equation (3). By using this simple income profile we avoid making assumptions about the timing of retirement and the specification of the household pension scheme, both of which vary by cohorts.

The top left graph in Figure 2 displays our estimates of raw as well as smoothed mean (after-tax) labor income growth rates over the life cycle.

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

[9] There are likely to be other costs associated with moving, such as the time spent searching for an attractive new house, preparing one's house for sale, or settling down in a new home. By including only the observable components of transactions costs, we indicate that our parameterization of $\kappa_p$ and $\kappa_s$ is probably best seen as a lower bound.

Figure 2: Life Cycle Profiles of Household Labor Income and Demographics




*Notes*: In the top two graphs, the dashed lines are raw estimates from data. The solid line in the top left graph is the approximation by third-order polynomial. Solid lines in the top right graph are approximations by fourth-order polynomials.

When households enter the labor force around 27 there is a strong labor income growth, which implies that at the beginning of working life there is a sharp increase in the level of income . Labor income growth declines sharply until age 40 and then it falls moderately toward the end of the life cycle.

*Age-varying Labor Income Risk*

To estimate idiosyncratic labor income risks over the life cycle, we consider the following regression:

$$\log Y_{ia} = f_i + Z_{ia}\beta + y_{ia} \,,$$

where $f_i$ is a household fixed effect and $Z_{ia}$ is a vector of observable household characteristics at age $a$. These include an age dummy, education, family size, family composition, marital status, nationality and geographical region. The object of interest here is $y_{ia}$, which is the unexplained stochastic component of labor income.

The dispersion of income during the early stages of life gives rise to differences in the timing of housing purchases. Allowing for age-dependent variances of permanent and transitory shocks to income is therefore crucial for the ability of our model to match the data. The stochastic component of income follows

$$\Delta y_{ia} = \psi_{ia} + \Delta \xi_{ia} \, .$$

As shown in Blundell, Pistaferri, and Preston (2008), age-varying variances of permanent shocks are identified by

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

and age-varying variances of transitory shocks are identified by

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

Four years of data, from $a-2$ to $a+1$, are needed to identify the variance of permanent shocks at age $a$. Three years of data, from $a-1$ to $a+1$, are needed to identify the variance of transitory shocks. To estimate our structural life cycle model in the second step, we need age-dependent variances for ages 27 to 90. Because the age of households in the data ranges from 19 to 111, age-dependent variances can be identified.

The top right graph shows that while variation in the transitory component of labor income remains quite stable through life, variation in the permanent component of labor income declines sharply during the first decade of working life. At the beginning of working life, great variation in the levels of permanent income leads to a wide distribution of expected lifetime income. Close to age 40, the variance of transitory shocks starts to surpass that of permanent shocks, at which point transitory shocks become the dominant source of income uncertainty.

*Conditional Probability of Survival*

We assume that before the age of 67, which is the official retirement age, the probability of death is zero. Thereafter it is positive. Using official data on death rates, we calculate the conditional probability of survival for males during and after retirement. As characterized in the bottom left graph of Figure 2, the conditional probability of survival is averaged over 5 years and thus it appears as a step function. We use this conditional probability of survival over age as $p^S_a$ in our model.

*Household Composition*

Household size and composition vary over the life cycle. This demographic change affects both the shape of consumption profiles and the relative expenditure on non-housing and housing consumption. The bottom right graph of Figure 2 profiles how many adults and how many children households typically consist of at various stages of life cycle. Both are hump-shaped. We use these two profiles for $N_a^{Adult}$ and $N_a^{Children}$ in our model.

*Initial Distributions*

We sort the net worth of 26-year-old households in ascending order and divide them into 20 equal-sized groups. For each of the 20 net worth groups, we calculate mean net worth, mean housing, mean income, and homeownership rate. Table 5 in Appendix D displays these statistics. In simulating household profiles in our model, we assume that households enter the life cycle with an equal probability of belonging to any given net worth group. Within each group, households start the life cycle with the group's mean level of net worth and income, and if they are homeowners, their housing size is equal to the mean level of housing. The share of homeowners is equal to the homeownership rate in that group. In short, we calculate in the data a non-parametric joint distribution of net worth, housing, and income at the beginning of the life cycle, and the initial balance sheets of our simulated households are draws from that distribution.

*Other Parameters*

In Table 3, we list other first step estimates of our parameters, including the risk free interest rate, the borrowing rate, housing depreciation rate, and minimum housing.

### 4.3 Second Step Estimation

In the second step estimation, we employ the simulated method of moments to estimate household preference parameters. These parameters include the coefficient of relative risk aversion $\rho$, the discount factor $\beta$, the elasticity between non-housing consumption and housing services $\theta$, the share of non-housing consumption at the beginning of the life cycle $\alpha$, the service flow from owner-occupied housing $\zeta$, the weight on bequest $\varphi$, and the influence of household composition on the share of non-housing consumption, $f_a$ and $f_c$.

*Targets in the Data*

Our objective is to develop a model that captures the dynamics of household balance sheets over the life cycle seen in the data. Therefore, it is natural to target the age profiles of median net worth and median housing in the data.[10] Because housing gives rise to potential leverage, and because the relationship between leverage and the consumption response to wealth changes hinges crucially on the housing decision, the distribution of housing across households is important. We therefore include one additional set of moments: the age profiles of the homeownership rate. Altogether, we have 192 moments and 8 preference parameters.

*Initial Values of Parameters*

To minimize the cost of computation and increase the probability of finding the global minimum, we start our search of parameters with values that are consistent with macro and micro evidence under some simplifying assumptions of the model. Appendix E shows that under these assumptions $\alpha$, $\theta$, $\zeta$, $f_a$, and $f_c$ can be estimated directly. We use these estimates as the starting point of our estimation.

*Estimation Results*

Table 3 displays our estimation results. All of our preference estimates are in line with the literature. For example, our estimated coefficient of relative risk aversion, $\rho$, is less than 2—a result that is similar to Chetty (2006). Because 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 provides identification of the discount factor $\beta$ because a more patient household would on average hold more wealth. The curvature of the age profile of net worth pins down the coefficient of relative risk aversion $\rho$. Because $1/\rho$ 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. The parameter that governs non-housing consumption, $\alpha_a$, is identified by the share of non-housing consumption as well as the homeownership rates. The relative weight with which households value bequest, $\varphi$, is driven by the level of net worth at the end of the life cycle.

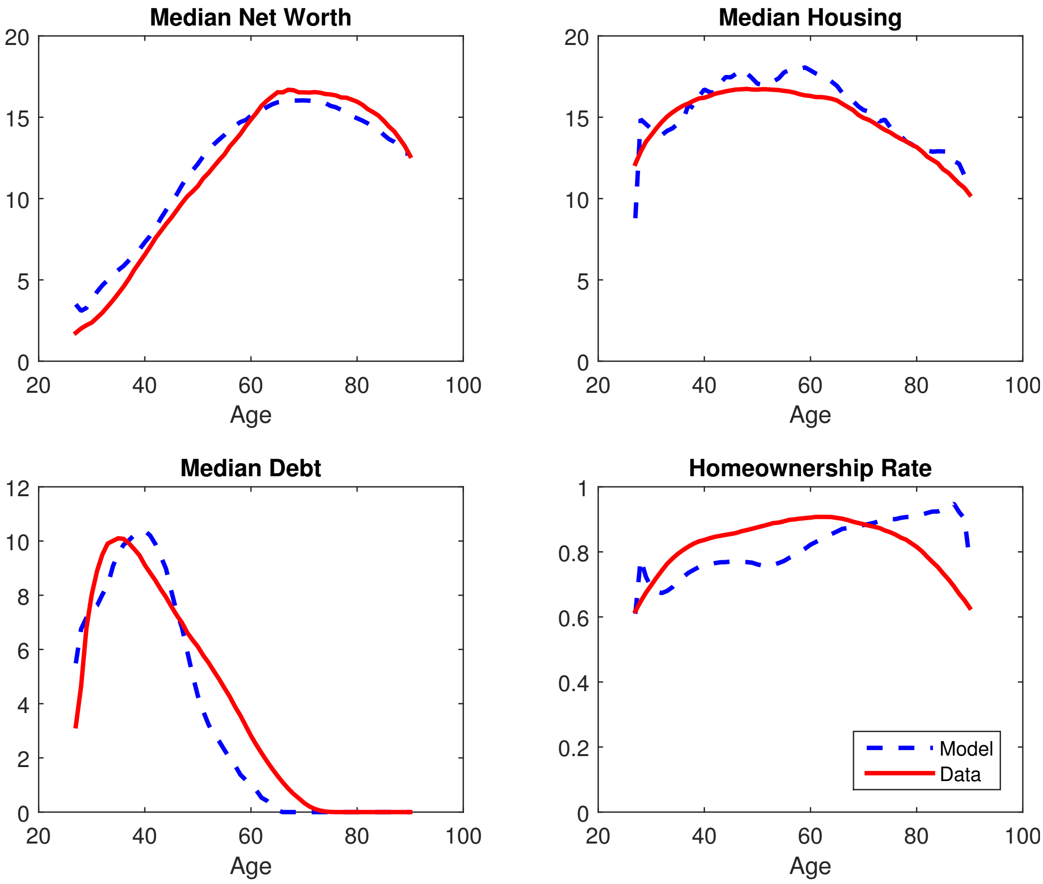
[10] In our model, there are two types of assets: housing $H$ and financial assets $A$. $A$ captures households' debt when it is negative and financial assets when it is positive. In the data, households often hold debt and financial assets simultaneously. For this reason, we do not target debt explicitly.

Table 3: Parameter Values of the Model Economy

| Estimates | Parameter | Value | Target/Source |
|---|---|---|---|
| **First Step** | | | |
| **Demographics** | | | |
| Lifespan | $T$ | 90 | |
| Conditional probability of survival | $\{p_a^S\}$ | Figure 2 | SSB* |
| Mean number of adults | $\{N_a^{Adult}\}$ | Figure 2 | Data |
| Mean number of children | $\{N_a^{Children}\}$ | Figure 2 | Data |
| **Income process** | | | |
| Permanent income growth rate | $\{\Gamma_t\}$ | Figure 2 | Data |
| Variance of permanent income | $\{\sigma_{\Psi,t}\}$ | Figure 2 | Data |
| Variance of transitory income | $\{\sigma_{\Xi,t}\}$ | Figure 2 | Data |
| **Borrowing** | | | |
| Risk free rate | $r$ | 0.016 | Norges Bank |
| Borrowing rate | $r_b$ | 0.054 | 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 of purchase | $\kappa_p$ | 0.025 | |
| Transaction cost of sale | $\kappa_p$ | 0.025 | |
| Minimum housing | $\underline{h}$ | 8.2 | Data** |
| **Second Step** | | | |
| **Preference** | | | |
| Initial weight on consumption | $\alpha$ | 0.55 | |
| Adults' impact on consumption weight | $f_a$ | 0.47 | |
| Children's impact on consumption weight | $f_a$ | 0.12 | |
| Discount factor | $\beta$ | 0.93 | |
| Coefficient of relative risk aversion | $\rho$ | 1.20 | |
| Elasticity of substitution | $\theta$ | 0.49 | |
| Utility of owning | $\zeta$ | 0.09 | |
| Bequest weight | $\varphi$ | 12.3 | |

*Statistics Norway.
** We use the 5th percentile of housing value in the data.

Figure 3: Household Balance Sheet Over the Life Cycle: Model and Data




*Notes*: Throughout, household profiles are in 100k Norwegian Krones, indexed to the 2000 price level.

# 5 Model vs. Data

We now evaluate how well our quantitative model performs in fitting the life cycle profiles of household balance sheets in the data. Thereafter, we explore the model-implied relationship between leverage and households' marginal propensity to consume out of wealth changes, and we compare it to the regression results in section 3.2.

## 5.1 Life Cycle Profiles

Figure 3 shows that under the estimated parameters, our model generates life cycle balance sheet profiles that resemble those in the data.

First, the hump-shaped profile of median net worth, which reflects wealth accumulation before retirement and decumulation after, exists both in the data and in the model. Three factors are at work here. Labor income uncertainty induces precautionary savings early in life. Decreasing income growth rates over the life cycle lead to savings for retirement in midlife. Bequest motives prevent households from depleting their wealth after retirement.

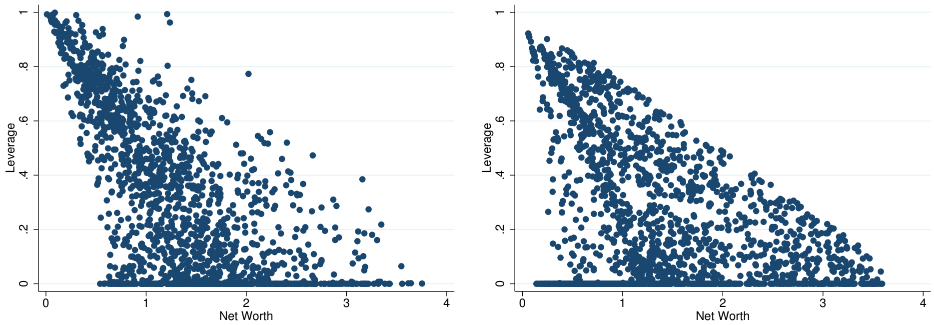
Second, median housing wealth is hump-shaped in the data as well as in the model. Note that the median profile of housing wealth is not tracking a single household. Thus the rise in the level of housing before the age of 60 partly reflects an increasing homeownership rate and partly reflects housing upgrades among existing homeowners. The fall in the level of housing afterwards indicates that households late in the life cycle move into houses of smaller size. Except for the early years of the life cycle, median housing wealth in the model closely tracks the data. In fact, the discrepancy in the early years is probably due to our abstracting from house price dynamics. As Table 5 shows, households in the first few net worth deciles have negative net worth and high levels of housing. Perhaps these households hold on to a high level of housing when their net worth is low because they expect house price appreciation in the future. In our model—and in the absence of house price appreciation—owning so much housing wealth when net worth is low is not optimal.

Third, in our model house purchases are mortgage-financed for a median household. Debt is present over most of the life cycle. The median household only pays off debt near retirement. Although we do not directly target the debt in the data, our model fits the life cycle profile of debt quite well. This gives us confidence that the leverage ratio in our model is similar to that of the data, despite the fact that our model summarizes mortgage debt and financial assets in a single variable.

Finally, although our model generates the correct average homeownership rate, it does not capture the shape of the homeownership rate over the life cycle. This is probably due to the fact that our model does not acknowledge that there is heterogeneity in the preference for owning. In our model, old households rarely rent for two reasons: first, owning provides higher utility than renting per housing unit; second, as a bequest, housing is almost as good as financial assets. Consequently, the homeownership rate in our model rises slightly over the life cycle. Of course, the fact that old households have a disutility from owning a house that they cannot maintain might explain why in the data homeownership declines after retirement.

Regarding the cross-sectional distribution of net worth and leverage, a comparison of Figure 4b, which is simulated from the model, and Figure 4a which displays the Norwegian data, reveals that our model captures the heterogeneity in the data reasonably well.

Figure 4: Heterogeneity in Household Leverage and Net Worth




(a) Data (b) Model

## 5.2 Leverage and the Consumption Response to Wealth Changes

Next we address our main question, which regards the importance of leverage for the marginal propensity to consume. Focusing on data generated by our model, we repeat the exercises undertaken in Section 3.2. To render the sample comparable to that in the actual data, we restrict our analysis to simulated households that are between 30 and 80 years of age.[11] To control for household characteristics, we use age polynomials up to the third order and their interaction terms with the change in wealth. Note that by construction there is no preference heterogeneity among households of the same age in our model.

Table 4 presents the regression results from our model along with the key estimates from the Norwegian data that we saw previously in Table 1a and Table 1b. Again, the main parameter of interest is the interaction effect reported in line 8 of the table. We see in both the simulated data and the actual data that the role of leverage for the consumption response to wealth changes is very similar: that is, the coefficients of the interaction effect are both statistically significant and economically important (the point estimate slightly above 0.2). Given our model's simplicity and in particular the fact that it relies on limited preference heterogeneity, this result is somewhat sur-

[11]The age distribution is almost uniform in our simulated data but far from uniform in the actual data. As a result, our simulated data have many more young households and old households. In our simulated data, about 20% households are under age 30 or above 80; in the data, these age groups account for less than 10% of households. To mitigate this issue, we drop households at the very beginning and at the very end of the life cycle.

prising. Our model generates heterogenous balance sheets only by carefully modeling the heterogeneity in housing choices. The regression results indicate that this source of balance sheet heterogeneity helps to account for the empirically observed link between leverage and households' heterogeneous consumption responses to wealth changes.

As is evident in Table 4, there are some notable discrepancies between coefficients in the simulated and the actual data. A model that successfully captures the entire distribution of wealth across households at different ages in the data probably would produce similar results, but that is beyond the scope of this paper. We leave it for future research.

In our model household balance sheets and age affect the heterogeneity in the marginal propensity to consume out of wealth. To understand the role of leverage, we focus on households that are of a small age group. Specifically, we consider households whose age is between 30 and 35, which is the time when most of them have leverage. We first sort simulated households by their wealth-to-income ratios and we then divide them into 8 equal-sized groups in ascending order. Within each wealth-to-income-ratio group (WG), we next sort households by their leverage and divide them further into 8 equal-sized groups in ascending order. This partition leaves us with 64 wealth-leverage groups of equal mass. For each of these groups, we calculate the average marginal propensity to consume out of wealth. Figure 5 reveals graphically the role played by leverage. Within each WG, the average MPC tends to increase as the leverage group increases from 1 to 8. The role of leverage is most apparent for groups that have a low wealth-to-income ratio because less wealthy households tend to have higher leverage. There is, however, a notable subtlety in Figure 5: for households that have lower leverage (such as those in leverage group 1), there is a greater probability that in the near future their liquid wealth will turn from negative to positive and thus the interest rate on their liquid wealth will change from the high borrowing rate to the low risk free rate. The potential decrease in the interest rate will give a small boost to the MPC out of wealth. As wealth increases, the possibility that the interest rate will decrease also increases. Therefore, we see in the figure that the MPC increases in wealth for the low leverage groups.

# 6 Policy Implications

## 6.1 Abrupt Credit Tightening

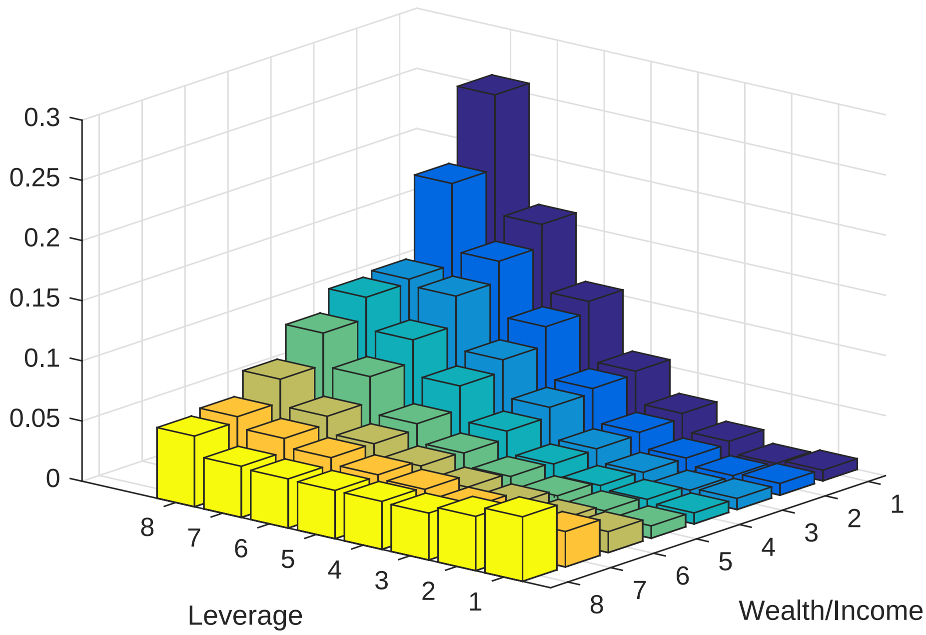
In the wake of the Great Recession, many economists have studied how credit crunches affect the economy. In our calibrated model, we focus on the quantitative implication of a particular type of reduction in credit availability: a

Table 4: The Role of Leverage in the Model and in the Data

| Dep.Var: | $\Delta C_t$ | | | |
|---|---|---|---|---|
| | (1) Simulation | (2) Data | (3) Simulation | (4) Data |
| $\Delta W_t$ | 0.527*** | 0.531*** | 0.203*** | 0.804*** |
| | (0.042) | (0.106) | (0.042) | (0.107) |
| $W_{t-1}$ | -0.004*** | -0.096*** | | |
| | (0.000) | (0.001) | | |
| $\Delta W_t \times W_{t-1}$ | -0.000 | 0.008*** | | |
| | (0.000) | (0.001) | | |
| $\frac{W_{t-1}}{Y_{t-1}}$ | | | 0.034*** | -0.012*** |
| | | | (0.000) | (0.000) |
| $\Delta W_t \times \frac{W_{t-1}}{Y_{t-1}}$ | | | 0.017*** | -0.010*** |
| | | | (0.000) | (0.000) |
| $lev_{t-1}$ | -0.091*** | -0.337*** | 0.147*** | -0.253*** |
| | (0.005) | (0.001) | (0.005) | (0.001) |
| $\Delta W_t \times lev_{t-1}$ | 0.200*** | 0.226*** | 0.259*** | 0.206*** |
| | (0.005) | (0.002) | (0.004) | (0.002) |
| Year# | | X | | X |
| $\bar{Y}$# | X | X | X | X |
| CHAR# | X | X | X | X |
| adj. $R^2$ | 0.316 | 0.346 | 0.346 | 0.335 |
| N | 144,246 | 1,346,264 | 144,246 | 1,346,264 |

*Notes.* This table presents coefficients from regressions relating the change in household consumption to the change in household wealth in the simulated data. For comparison purposes, column (2) reproduces the result in column (3) of Table 1a, and column (4) reproduces the result in column (4) of Table 1b. Throughout, standard errors are in parentheses. *** indicates that coefficients are statistically different than 0 at the 1% confidence level.

Figure 5: Average MPC by Wealth and Leverage Groups in the Simulated Data




*Notes:* This graph presents the average marginal propensity to consume out of wealth for households whose age in the simulated data is between 30 and 35. The wealth-to-income ratio is sorted ascendingly into 8 equal-sized groups. Within each wealth-to-income-ratio group, leverage is sorted ascendingly into 8 equal-sized groups. Group 1 on either axis has the smallest values of the corresponding variable.

sudden reduction in loan-to-value (LTV) limit. As Geanakoplos and Fostel (2008) and Geanakoplos (2010, 2014) emphasize, the abrupt change of loan-to-value requirement on new loans is a crucial source of economic crashes.

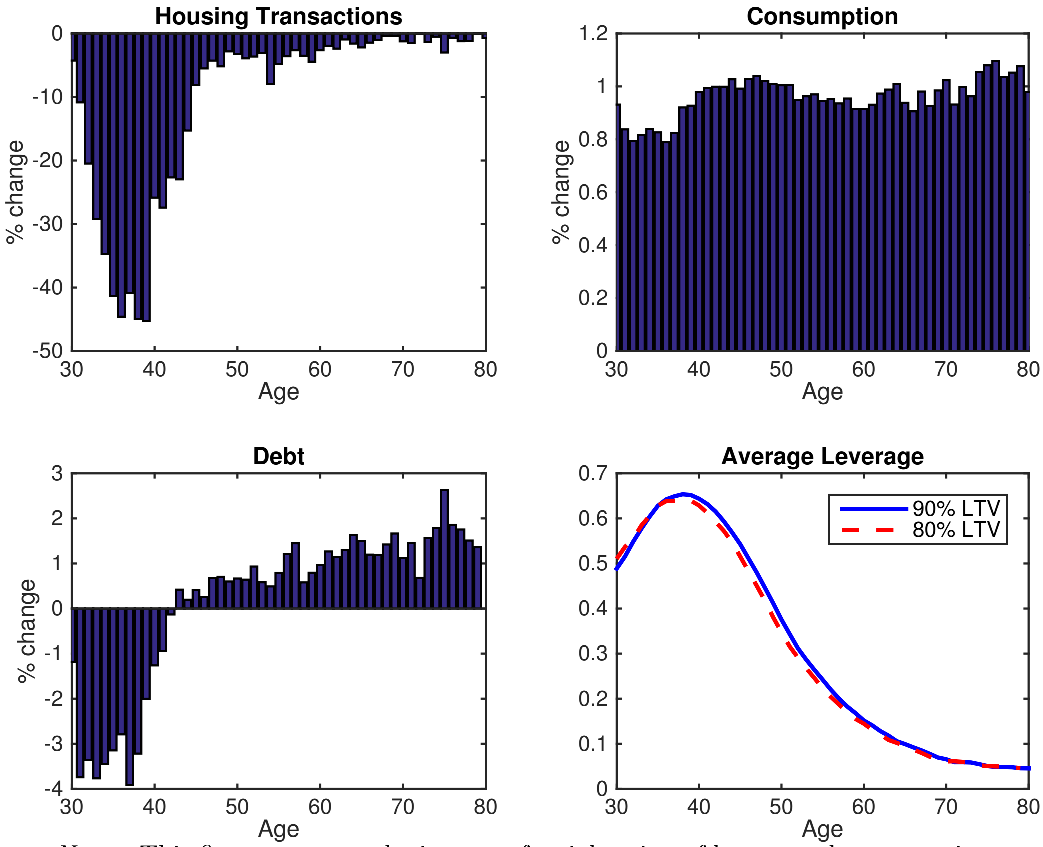
Our model is well suited at assessing the immediate response of the economy to a policy change. Being a partial equilibrium model, it falls short of depicting completely the short and medium run dynamics of consumption and housing choices. Nonetheless, with its close attention to micro-level adjustment, our model provides important quantitative insights into the channels through which the effect of credit crunch takes place.

We consider the immediate response of households when the LTV limit on new loans is reduced from 90% to 80% on new loans. We assume that there are two periods. In period 0, households are at their optimal choice of consumption and housing; the LTV constraint is 90%. At the beginning of period 1, there is a sudden and permanent change in the LTV limit from 90% to 80%. We then compare how households respond with and without the period 1 policy change.

The first three graphs in Figure 6 depict the percentage change in some key variables under the low LTV limit and under no policy change. The top left graph in Figure 6 shows the main contractionary effect of the policy change on the housing market. Under the policy change the number of housing transactions in our simulated economy falls by 10.2%. Most of the fall is concentrated among young households. The top right graph, in contrast, shows that rather than falling, consumption for almost all households increases by about 1%. Intuitively, a sudden increase in the down payment requirement from 10% to 20% forces some potential buyers, particularly the young, to delay their housing purchases. Young renters who can no longer afford homeownership increase their non-housing consumption. Existing homeowners who would otherwise increase their housing stock find themselves constrained by the new policy, which applies to new loans, and they therefore hold on to their existing houses and increase non-housing consumption instead. The implication for debt, however, is different among households. On average, the subdued housing transactions lead, on the one hand, to less mortgage debt among young households (due to delayed housing purchases) and, on the other, to increased borrowing among existing homeowners (due to increased consumption), as is shown in the bottom left graph. The bottom right graph shows that the impact on the average leverage of the economy is limited (a reduction of 5%).

Our results suggest that a realistic reduction in credit availability in mortgages alone leads to a quantitatively moderate consumption response and a large housing transaction response. In fact, consumption increases by a small amount, housing transactions drop abruptly, and the debt-to-housing ratio

Figure 6: Impact of Tightening in LTV Constraint




*Notes.* This figure presents the impact of a tightening of loan-to-value constraint from 90% to 80%. We compare households' behavior under 80% LTV constraint in period 1 to their behavior under 90% LTV constraint in the same period.

barely changes. Given the potential general equilibrium effect, reduced activity in the housing market probably places downward pressure on house prices, which in turn decreases households' wealth and reduces households' borrowing capacity. The decrease in house prices, when it is sufficiently large, will put highly levered households underwater and have further ramifications for consumption. This recalls features of the onset of the Great Recession: when subprime mortgages in the U.S. turned bad in 2006, down payment requirements for new loans dramatically increased, and housing prices started to fall. However, consumption continued to increase until 2008, when it fell sharply. The debt-to-GDP ratio plateaued in late 2007.

In our policy exercise the channel through which a credit crunch affects the economy differs from those considered in Eggertsson and Krugman (2012) and Guerrieri and Lorenzoni (2011). These papers examine how a reduction in credit availability to consumers pushes the economy to the zero lower bound, which exacerbates the fall in consumption and aggregate demand. But the models therein are very stylized and do not include leverage. An exogenous reduction in the debt limit in these models forces net-worth-constrained households to repay their debt and thus it reduces consumption. In our model, leverage is endogenous and households hold assets and debt simultaneously. From the perspective of household balance sheets at the micro level, credit availability is quantitatively far more important for housing than is its direct effect on consumption. We conclude that, in addition to the zero lower bound channel, the housing wealth channel might be key to understanding the effect of a reduction in credit availability.

### 6.2 Consumption Responsiveness and the Loan-to-Value Ratio

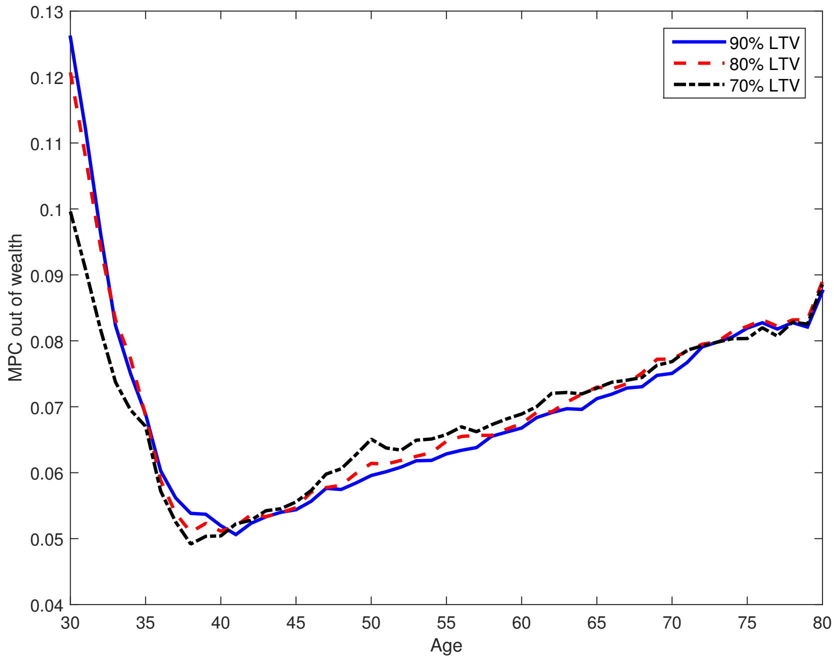
One widespread narrative of the Great Recession is that negative shocks to household wealth were propagated by high household leverage. Indeed, this is a natural interpretation of the regression results provided by Mian, Rao, and Sufi (2013), Baker (2015), and in this paper. Partly for this reason, policymakers have been urged to implement tighter regulations that restrict the loan-to-value ratios at which banks issue mortgages to households. However, to address the effectiveness of such policies, one cannot simply rely on evidence from the past, but must use structural models. Our framework is well suited to give a partial equilibrium answer to this question, and we ask: Is consumption less sensitive to wealth changes in a world where loan-to-value limits are low?

To answer this question, we compare the marginal propensity to consume out of wealth in steady states that differ in terms of their LTV-ratios only. We consider three ratios: 70%, 80% and 90%. Figure 7 shows the result for each age group separately.

First, we note that the MPC always displays a U-shaped pattern over the life cycle. Three factors are at work here. First, wealth accumulation over the life cycle helps households build up buffers against income risk and hence decreases MPC. Second, as the remaining life horizon shortens, the resolution of uncertainty increases the MPC. These two factors drive MPC in opposite directions over the life cycle. Our calibrated model implies that when households are young wealth accumulation dominates the age-MPC relationship, while thereafter the second effect dominates. The third factor is leverage, and its role differs by age; it is closely related to the timing of when housing is affordable.

More importantly, we see that economies with different LTVs do not have very different marginal sensitivities of consumption to wealth changes. A

Figure 7: Marginal Propensity to Consume Out of Wealth



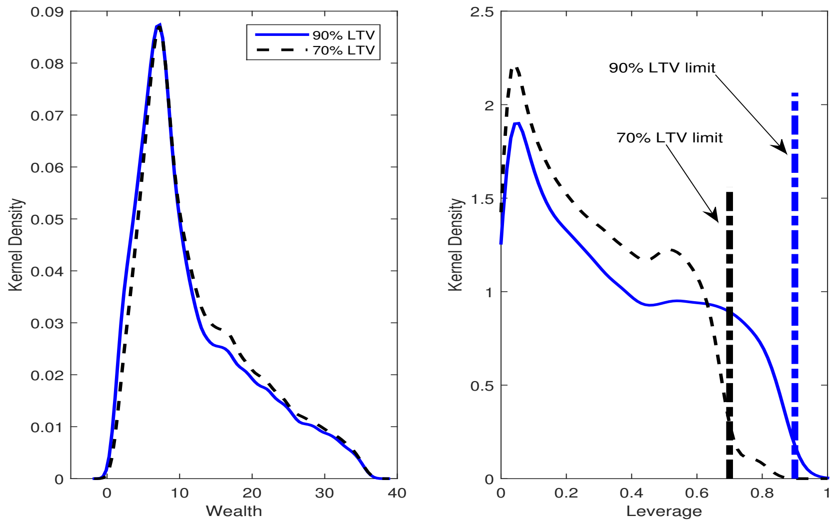

tighter LTV policy reduces the MPC for young households only and it raises slightly the MPC for middle-aged and older households. The key intuition here is that households make *joint* decisions about their housing and financial wealth holdings. When the LTV limit is high (low down payment), young households are able to finance a housing purchase with a large mortgage. When the LTV limit is low (high down payment), young households simply postpone housing purchases until they have accumulated enough wealth. In either case, their optimal choice is to finance their housing with as much mortgage as possible. As a result, young households under a low LTV limit tend to hold more liquid balance sheets and so their consumption responds less strongly to wealth changes. However, when the purchase decision is postponed, the propagation of illiquidity on consumption sensitivity simply shifts to a later point in life. We therefore see that when there is a lower LTV limit, the MPC becomes slightly higher for middle-aged and older households.[12]

This can be best understood by examining Figure 8, which compares the distribution of wealth and leverage under the highest and lowest LTVs.[13] The

[12]The average MPC increases somewhat even for households above 50 years of age is because a tighter LTV limit affects consumption at all wealth levels, although the effect is small for the wealthiest of households.

[13]We use kernel density estimation to approximate the probability density function of

Figure 8: Distribution of Wealth and Leverage




left graph shows that the distribution of wealth in the economy almost does not change under different LTVs. Instead, what changes is the composition of household balance sheets. For a given LTV constraint, households optimally choose their leverage to balance their need for liquidity and housing. The right graph shows, not surprisingly, that under the low LTV ratio the distribution of leverage shifts to the left, which indicates that the average leverage is now smaller. However, the share of households that are close to the LTV constraint is *not* lower, and this is what really matters for the average MPC of the economy. In fact, calculation of our simulated economy reveals that under the 70% LTV constraint, 5.9% of households are within the top 20% of the LTV constraint. Under the 90% LTV constraint, only 4.2% are within the top 20%.[14]

Note that here we take the magnitude of wealth shocks as given. Thus, our exercise does not account for the fact that household wealth itself becomes more sensitive to asset price movements when leverage is high. Our results indicate that this is the channel through which more stringent LTV limits might dampen consumption's sensitivity to various shocks.

wealth. Leverage is bounded from above by the LTV constraint. However, due to kernel smoothing, the density of leverage that exceeds the LTV ratio in the graph is positive.

[14]For the economy with 90% LTV constraint, the top 20% of the LTV constraint is the share of population whose leverage is between 0.72 and 0.9; for the economy with 70% LTV constraint, it is between 0.56 and 0.7. The share of population who has positive leverage is similar, 64% and 63.2% under 90% and 70% LTV constraint, respectively.

## 7 Conclusion

We provide new empirical evidence at the micro level that the composition of household balance sheets and especially their housing leverage ratio matters for the marginal propensity to consume out of wealth over and above their total wealth. We find that this relationship between leverage and the consumption response to wealth changes is not primarily driven by heterogeneity in observed or unobserved household characteristics. Such balance-sheet effects are not present in the conventional single-asset buffer stock saving models. We therefore develop a model that can quantitatively account for the life cycle profile of household balance sheets. The ability of the model to reasonably match housing choices is essential for its capacity to match balance sheet profiles. Our model successfully accounts for the empirical association between leverage and the marginal propensity to consume out of wealth. The key mechanism is that transaction costs in the housing market induce households that are moving along the housing ladder to adjust housing stock infrequently. Housing is therefore less liquid than financial wealth. Housing transactions imply a shift in the liquidity of household balance sheets. Thus, recent home buyers who have increased their housing stock are closer to their liquidity constraint, have excessively high housing relative to non-housing consumption, and have a strong desire to increase their non-housing consumption share. In contrast, recent home buyers who have reduced their housing stock are further from their liquidity constraint, have low leverage and low housing consumption, and have a weak desire to increase their non-housing consumption share. Given the important role that leverage plays in distinguishing between liquid and illiquid assets and in explaining consumption dynamics, we aim in future research to extend our analysis to the marginal propensity to consume out of different types of assets.

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# A Details of the Norwegian Registry Data

## A.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.[15] 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 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.

## A.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

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

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.

# B Details of the Households' Problem

In this section, we describe in detail the dynamic stochastic optimization problems of households introduced in Section 4.

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 conditional on renting or owning 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 motive is

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

where

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

is the utility of bequests and $W_{a+1} = A_a + H_{a+1}$ 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:

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

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

$$
\begin{aligned}
C_a &= \alpha_a \hat{C}_a \,, \\
S_a &= (1-\alpha_a)\hat{C}_a \,.
\end{aligned}
$$

The intertemporal optimal condition is:

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

with envelope condition:

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

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

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

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

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

The envelope condition is:

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

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:

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

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

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

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

The set of envelope conditions is:

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

*Consumption and housing in the last period*

Households' value function in the last period is:

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

For renters, the optimal composite consumption follows

$$(\hat{C}_T)^{-\rho} = \beta\varphi p^c_T W^{-\sigma}_{T+1} = \beta\varphi p^c_T(M_T - p^c_T\hat{C}_T)^{-\sigma},$$

and the marginal value of market resources is

$$\frac{\partial V^r_T}{\partial M_T} = \beta\varphi W^{-\sigma}_{T+1} = \frac{u'(\hat{C}_T)}{p^c_T}.$$

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

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

Hence $\hat{C}_T$ is a decreasing function of $\varphi$.

# C Numerical Solution to the Households' Problem

Our structural model involves discrete choices about transitions between renters and homeowners ($rr$, $rh$, $hr$, $hh$, $hh'$), and continuous choices about consumption ($C$) and housing ($H$). The presence of discrete choices induces multiple solutions to the same Euler equation and kinks in the value function, making it computationally intensive to accurately find solutions to households' problem. To tackle this issue, we first solve for policy rules and value functions conditional on discrete choices, and then use the upper envelope of conditional value functions as the unconditional value function. Specifically, the unconditional value function of renters is obtained by taking the upper envelope of value functions conditional on $rr$ and $rh$, and the value function of homeowners by taking the upper envelope of value functions conditional on $hr$, $hh$ and $hh'$. Conditioning on discrete choices, we use the first order condition(s) to solve for consumption and housing rules. To this end, we extend the endogenous grid point method by Carroll (2006) to the case of two continuous variables. To account for occasionally binding loan-to-value and loan-to-income constraints, we use a modified version of Hintermaier and Koeniger (2010). To deal with kinks of value functions efficiently, we employ an algorithm similar to that in Iskhakov, Jørgensen, Rust, and Schjerning (2014). Starting from policy rules and value functions in the last period, we iterate backward to obtain a set of age-dependent consumption and housing rules and value functions conditional on discrete choices. We then simulate 5000 households to generate simulated profiles. To further speed up computation, we parallelize the computation of household decisions based on their permanent income and parallelize the simulation based on the number of households.

# D Initial Distribution of Net Worth, Housing, and Income

Table 5 presents the initial distribution of net worth, housing and income in the data. In our simulation we draw from this joint distribution the initial values of household balance sheets.

# E Initial Values of Preference Parameters

Good initial values will speed up the estimation of our model and increase the probability of finding the global minimum. In this section, we derive moment conditions under some simplifying assumptions of the model. These moments are key to identifying parameters related to preference in our model. We use these parameter estimates as initial values for our second step estimation.

Suppose households are able to smooth housing consumption costlessly. Then the intratemporal optimality condition implies

$$\frac{C_a}{S_a} = \frac{\alpha_a}{1-\alpha_a} \,.$$

In our model, $S_a = \zeta H_a$ and $\alpha_a = \exp(\phi_a)/(1+\exp(\phi_a))$ where $\phi_a = \phi_0 + \phi_1 N_a^{Adult} + \phi_2 N_a^{Children}$. Thus we have

$$\frac{C_a}{H_a} = \zeta \exp\left(\phi_0 + \phi_1 N_a^{Adult} + \phi_2 N_a^{Children}\right) \,.$$

Taking logarithm of both sides yields

$$\log\left(\frac{C_a}{H_a}\right) = \log(\zeta) + \phi_0 + \phi_1 N_a^{Adult} + \phi_2 N_a^{Children} \,. \tag{4}$$

Thus $\phi_1$ and $\phi_2$ can be identified from a regression relating the ratio of non-housing and housing consumption to the number of adults and the number of children using the micro data. In addition, such a regression would imply a relation between $\zeta$ and $\phi_0$.

Table 5: Initial Distribution by Net Worth Group

| Group | Net Worth | Income | Housing | Homeownership |
|---|---|---|---|---|
| 1 | -16.87 | 3.06 | 15.64 | 0.25 |
| 2 | -7.03 | 3.01 | 13.33 | 0.55 |
| 3 | -3.44 | 2.33 | 13.33 | 0.36 |
| 4 | -2.27 | 1.97 | 13.24 | 0.22 |
| 5 | -1.52 | 2.06 | 13.72 | 0.20 |
| 6 | -0.86 | 2.10 | 13.78 | 0.19 |
| 7 | -0.27 | 1.99 | 13.76 | 0.17 |
| 8 | 0.01 | 1.25 | 14.04 | 0.04 |
| 9 | 0.24 | 1.99 | 13.92 | 0.16 |
| 10 | 1.05 | 2.56 | 14.24 | 0.49 |
| 11 | 2.66 | 2.82 | 14.45 | 0.83 |
| 12 | 4.68 | 2.76 | 15.49 | 0.95 |
| 13 | 6.78 | 2.57 | 15.70 | 0.98 |
| 14 | 8.98 | 2.53 | 16.32 | 0.99 |
| 15 | 11.27 | 2.32 | 16.83 | 1.00 |
| 16 | 13.75 | 2.21 | 18.07 | 1.00 |
| 17 | 16.56 | 2.09 | 19.70 | 1.00 |
| 18 | 20.02 | 2.13 | 22.40 | 1.00 |
| 19 | 25.73 | 2.12 | 27.71 | 1.00 |
| 20 | 51.66 | 2.56 | 43.14 | 0.99 |

*Notes.* Groups are based on 20 net worth quantiles. All levels are the mean of each net worth group in hundreds of thousands of Norwegian Krones that are indexed to the 2000 price level. Housing is the mean level of owner-occupied housing.

Next we add to our model the relative price of housing service to non-housing consumption, $p_t^h$, while maintaining the assumption of no transaction costs. We assume that the aggregate non-housing consumption and housing service are $C_t$ and $S_t$, respectively, and that the aggregate expenditure share on non-housing consumption in each year is $\bar{\alpha}$. The intratemporal optimality condition costs implies that

$$\frac{C_t}{S_t} = \frac{\bar{\alpha}}{1-\bar{\alpha}} \left(p_t^h\right)^{\theta-1} .$$

Taking logarithm of both sides yields

$$\log\left(\frac{C_t}{S_t}\right) = \log\left(\frac{\alpha}{1-\alpha}\right) + (\theta - 1)\log\left(p_t^h\right) \ . \tag{5}$$

To obtain the time series on the left-hand side of the above equation, we use aggregate expenditure share on housing and rents at the quarterly frequency and calculate its implied consumption to housing service ratio. To construct the relative price of housing service , we use quarterly data of house price index and CPI from 1999Q1 to 2009Q4 and take their ratio (with mean normalized to one) as a proxy for $p_t^h$. This results in an estimate of $\hat{\theta} = 0.497$ and an estimate of $\hat{\hat{\alpha}} = 0.725$.

Relating the time series results to cross-sectional results,

$$\alpha \approx \frac{\exp\left(\phi_0 + \phi_1 \bar{N}^{Adult} + \phi_2 \bar{N}^{Children}\right)}{1 + \exp\left(\phi_0 + \phi_1 \bar{N}^{Adult} + \phi_2 \bar{N}^{Children}\right)} \ ,$$

where $\bar{N}^{Adult}$ and $\bar{N}^{Children}$ are the average number of adults and children per family. Combining with estimates from equation (4), we obtain an initial estimates of $\hat{\zeta} = 0.22$ and $\hat{\phi}_0 = 0.12$.