The Distribution of Wealth in a Life-Cycle Model with Durables

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Supervisor: Professor Thomas Hintermaier

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Eric Lustenberger

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1 Introduction

Over the past decades the concentration of wealth has decreased dramatically. This has important social consequences, affecting democratic institutions. Even if the views of the extent of this rise in inequality are somewhat debated it clearly affects everyday life. Inequality is thus

Over the same time period, macroeconomics has seen a shift towards micro-founded analysis, which is based on the aggregation of optimal decision making at the individual level and thus providing a coherent and robust framework to all kinds of economical questions at the macro economic level. Initially predominantly featuring the representative agent version, a surge in computing power and numerical methods have enabled macroeconomists to deal with models incorporating a higher degree of complexity. One of these ramifications has led to include different forms of heterogeneity among agents. The endogenous wealth distribution in the standard incomplete market model provides a natural framework for the study of questions related to inequality. Such models provide the basis for the analysis of redistributional policies. They shed light on the underlying mechanisms leading to unequal distributions of wealth and consumption. In order to improve policy making it is crucial in understanding these mechanisms.

The main goal of this paper is to contribute to the net-worth literature by investigating the empirical prediction of the net-worth cross-section in the US. Doing so, using detailed micro-data for income as well as the net-worth distributions for three different age groups thus allows me to accurately illustrate, what part of the distribution can be explained by the model and where the model presents shortcomings. Moreover, I look at two important determinants, the income risk and the LTV-ratio by simulating unexpected changes to illustrate how these affect the distribution across different age groups and the consumption-savings decision across the life-cycle. Finally, I show that the initial portfolio allocation is particularly important to predict the the net-worth distribution of the youngest age group when calibrating the model.

I use detailed consumer data from Hintermaier and Koeniger (2011) to evaluate the out of sample prediction of the evolution of the net-worth distribution in the US in a model abstracting from durables. Modeling durables is particularly interesting, since they exhibit a dual-role. On the one hand consumers derive consumption services by holding durables, one the other hand, they may use these as collateral to borrow and thus transfer wealth across time. FernÃ¡ndez-Villaverde and Krueger (2011) show that this dual role is important to reproduce the non-durable consumption life-cycle profile. An abstraction from durables may therefore bias life-cycle profiles of non-durable consumption and thus the accumulation of net-worth in a model with one asset. Moreover, they point out that durables help to explain why households with higher life-cycle income save proportionally more than poor households. As the durable stock rises, liquid assets become relatively more attractive and thus rich consumers with a high durable stock will increase their liquid assets.Díaz and Luengo-Prado (2010) investigates the role of housing in the wealth-distribution in the US using an infinite-horizon model. I show that my model is able to accurately reproduce life-cycle profiles of the portfolio composition as well as non-druable consumption over the life-cycle observed in the data. In order to do so, I compare the simulated life-cycle profiles to the empirical data presented in other literature.

The first section discusses the theoretical literature, whose motive is to find determinants of net-worth and empirically validate these. The second section presents important empirical facts of the wealth distribution. In the third section I present the model. The fourth discusses the calibration and in the fifth I present the results. The sixth section concludes.

2 Modeling the wealth distribution

2.1 The Standard Incomplete Markets Model

The modeling of distributions requires some form of heterogeneity. The most common model used to achieve differences across agents is the standard incomplete markets model (SIM) (Heathcote, Storesletten, and Violante, 2009). In this model, ex-ante identical consumers are subject to uninsurable idiosyncratic income risks. In order to insure themselves against these income shocks agents accumulate precautionary savings. Since income histories vary according to the agent, these accumulate different amounts of savings resulting in an endogenous wealth distribution. An important feature is thereby the exogenously determined imperfect market structure, which leads to the accumulation of precautionary savings, since the trade of contingent claims is assumed away.[1] Consumers are thus limited to a certain choice of assets. The canonical version allows for a one-time period bond only – Commonly interpreted as net-worth holdings. The hypothesis of the complete market framework has been rejected by the vast majority of empirical research (Tideman and Weber, 2010). Deaton and Paxson (1994) show that the life-cycle profile of consumption inequality is increasing with age, a fact that would be inconsistent with complete markets. Moreover, the assuming away markets, where individuals can trade contingent claims to insure themselves against the idiosyncratic wage shocks is justified by moral hazard problems (FernÃ¡ndez-Villaverde and Krueger, 2011). While in some rare cases - such as when only studying aggregates, it may still be sufficient to consider a complete market framework, when considering wealth-distributive questions, the imperfect market assumption is both necessary from a theoretical perspective and well-founded from an empirical perspective. It remains to discuss the whether it makes sens to treat distributive issues from a life-cycle point of view. This model is based on the works of Bewley (1977), Aiyagari (1994), Huggett (1993).[2]

(MAKE SHORTER AND SIMPLER!!!!)

2.2 The Life-Cycle Feature

One important extension to the standard version, which was based on infinite-horizon models, for understanding the wealth distribution was the life-cycle model. This extension to the first versions of the SIM was made by İmrohoroglu, Imrohoroglu, and Joines (1995), Ríos-Rull (1995) and Huggett (1996).

The choice to study the empirical validity of a life-cycle model, which produces a net-

[1]Note, in a complete market framework consumers could perfectly diversify away idiosyncratic risks (Tideman and Weber, 2010).

[2]These types of models are thus sometimes also referred to as Bewley-Models.

wealth distribution arising from rational choices of consumers subject to income uncertainty, allows for a detailed analysis of consumption and savings behavior over a person's live-span. Explicitly modeling an agent's life-cycle, thus allows for some forms of heterogeneity across ages – As I will discuss further below, this feature is particularly interesting since there are strong heterogeneities across ages in the distribution of wealth in the data. One important component is the modeling of a retirement period, introducing life-cycle risk to precautionary savings i.e. consumers need to accumulate enough savings during their active working life in order to smooth consumption across their whole life-span. Another important feature of realism is the modeling of an experience premium and stochastic death probabilities.

The more recent literature on determinants of the net-worth distribution, almost unanimously employs versions of this type of models and enriches the standard version with various heterogeneities across the life-cycle in order to improve its prediction of the net-worth distribution. (CITE BETTER IN THIS SUBSECTION I.E. EXAMPLES OR PEOPLE WHO SHOW THAT THESE FEATURES ARE IMPORTANT!!!!!)

2.3 Wealth Distribution Literature

Although, the SIM model is used to study a variety of different economical questions (TO CITE A FEW), the endogenously generated distribution of wealth within the model, makes it a natural candidate to study the wealth-distribution.

Gourinchas and Parker (2002) and Cagetti (2003) look at savings behavior over the life-cycle; Castaneda, Diaz-Gimenez, and Rios-Rull (2003) evaluate the prediction of the cross-section and Hintermaier and Koeniger (2011) study of distributional dynamics, to name a few. More recent literature has primarily focused on modeling the the right tail of the wealth distribution, which is particularly challenging, as the canonical SIM fails to produce the extreme density of wealth found among the richest in empirical data (see for example: Fella and De Nardi (2017)). A commonly used approach entails modeling extreme income shocks in order to provoke precautionary savings to match the vast accumulation of assets by the very top of the wealth distributionand is based Castaneda et al. (2003) ((Díaz and Luengo-Prado, 2010) or (Kaymak and Poschke, 2016) for a more recent implementations). Krusell and Smith (1998) were the first to point out that a stochastic discount factor across dynasties can account for the variance of the cross-sectional distribution of wealth and does increase the wealth concentration among the richest. Other approaches are: A heterogeneous rates of return Benhabib, Bisin, and Zhu (2011), a richer earnings process (De Nardi, Fella, and Pardo, 2016) or the role of entrepreneurship (Cagetti and De Nardi, 2009). De Nardi and Yang (2014) show that adding voluntary bequests and intergenerational transmission of earnings drastically improves the model's prediction for the empirical cross-sectional differences in wealth at retirement as well as their correlation with lifetime incomes. Although these additional modeling features are able to better approximate the right tail of the wealth distribution, they still fail to produce a satisfying representation. [3]

Whereas the literature demonstrating that a plaubily parameterized version of the SIM can quantitatively explain features of the net-worth distribution is quite large, few of these models incorporate durables.

2.4 Durables and the Net-Worth Literature

Besides the authors mentioned in the introduction, a few others investigate the importance of modeling durables. Yang (2009) shows that borrowing constraints are important in explaining the accumulation of housing assets early in life. Gruber and Martin (2003) show that durables are important for the accumulation of precautionary savings.

(((((((((demonstrate that a plausibly parameterized version of their models can quantitatively explain empirical findings as arising from rational choices of consumers facing an increasing wage profile and income uncertainty.)))))))))

3 Facts about the Net-Worth distribution

Net-Worth and Changes across age groups There are substantial differences in the net-worth distribution across different age groups. Table 1 displays the gini-coefficients and the means for three different age groups, both for the whole sample, as well as up to

[3] For a more indebted review and the shortcomings of the different modeling approaches of this literature, see (Fella and De Nardi, 2017).

the 90th percentile.[4]

Table 1: My caption

	Age 26-35	Age 36-45	Age 46-55
Full sample			
Mean	2.28	5.90	12.49
Gini coefficient	0.824	0.765	0.765
Sample $\leq$ 90th pctile			
Mean	0.80	2.36	4.81
Gini coefficient	0.713	0.596	0.564

The average wealth holding is more than 2 times larger with each age group, for both the full distribution and the distribution up to the 90th percentile. Mean wealth thus increases substantially across age groups. While average wealth is increasing, the gini-index indicates that the within age group inequality tends to be increasing. The only exception is the stagnation between the older age groups for the full distribution. Hintermaier and Koeniger (2011) show that this pattern holds true for eight surveys from 1983 to 2007, with the exception that inequality tends to increase between the last two age-groups for the whole sample.[5] (ADD OTHER NEWER SOURCE!!!)

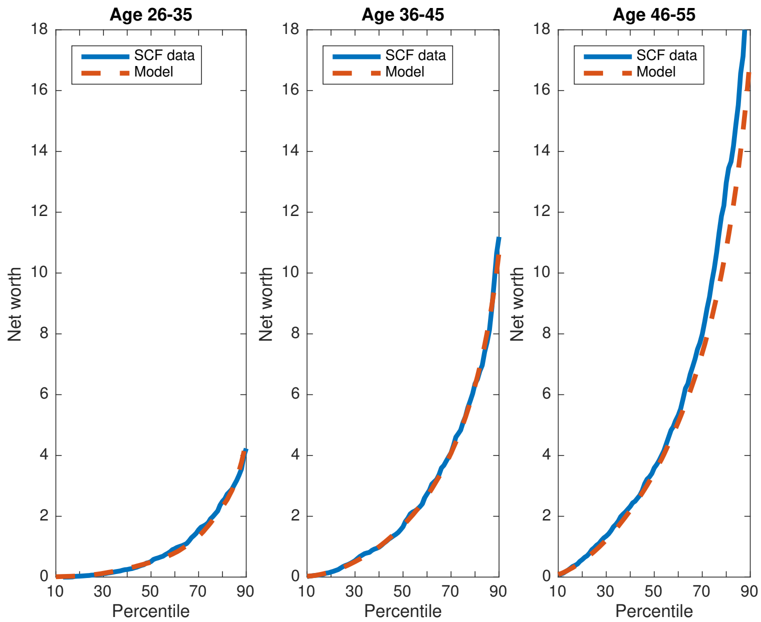
Furthermore, the differences between the full sample and the 90th percentile sample indicate that the wealth held by the top 10% is quite significant and its magnitude is relatively increasing in the age groups.
Figure 1 plots the detailed net-worth distribution for different age groups of the US in 2004 for the distribution up to the 90th percentile, as well as the full distribution. The data is SCF data from Hintermaier and Koeniger (2011).

Portfolio composition and the importance of Durables Two things are particularly noteworthy about durables. First, households in the bottom 90% hold almost their entire wealth in durables (citepkuhn et al). Using data from the SCF 1998 review, Díaz and Luengo-Prado (2010) point out that housing represents 96.3% of their total wealth.

[4]The table corresponds to the column for the SCF 2004 US data in Table 2 of Hintermaier and Koeniger (2011).

[5]See Table 2 in their paper.

Figure 1: Average Durable Holdings over the Life-Cycle



CHANGE THE BLOODY COLOURS!!!! IT IS THE SAME AS IN HINTER-MAIERS! NEED TO INDICATE THE MEASURES. JUST VERY STANDARD! NEEDS TO BE UPDATED

Whereas, to top 20% hold 26.8% of their total wealth in housing. Secondly, as can be expected from the evidence discussed above, Yang (2009) and FernÃ¡ndez-Villaverde and Krueger (2011) show that a similar picture can be painted, when one compares the average wealth portfolio across age groups. Young household tend to hold most of their net-worth in durables, and only start to accumulate liquid assets later in live. (FIND BETTER EVIDENCE!!!!)

This evidence suggests that it might be particularly important to model durables, when considering consumers aged 26 to 55 and focusing on the bottom 90% of the wealth distribution and if indeed, as FernÃ¡ndez-Villaverde and Krueger (2011) suggest, durables are important for the accumulation of wealth. (RETHINK THAT LAST PHRASE!)

4 Research Strategy

As discussed above, the modeling of the top of the wealth distribution is still unsatisfactory, unless one models extreme income shocks. The method introduced by Castaneda et al. (2003) is based on calibrating the income process in order to match the Lorenz curves of both earnings and wealth inequality and is thus not estimated based on micro-level data on earnings. This application, although able to match the right tail of the wealth distribution, therefore uses cross-sectional moments rather than household level data on earnings dynamics over time. The advantage is to get around the issue of over-sampling and top-coding for the richest (Heathcote et al., 2009). It, however, is unclear, whether the actual earnings process can produce the strong concentration of wealth at the top of the distribution (Fella and De Nardi (2017). Hintermaier and Koeniger (2011) propose an alternative strategy, namely to focus on the the wealth distribution up to the 90th percentile. Moreover, they focus on consumers between the ages 26 and 55 for whom changes in labor earnings are most relevant and that are not affected by measurement problems due to changes in the pension plans, which are poorly measured by the SCF Data. As these authors point out, this strategy is robust if general equilibrium feedback effects on the consumers excluded do not adversely affect the result.

4.0.1 Partial Equilibrium

Last but not least, partial equilibrium as modeling choice has to be discussed briefly. (????????????????)

(copy paste from hintermaier 2011 Note that we assume that changes in the domestic supply of assets do not affect do not affect the interest rate. As in a small-open economy, this price is determined exogenously (on the world markets.) [6])

The first quantitative was based on the following the work of Kydland and Prescott (1982) was based on the representative agent paradigm. One of the main reasons of abstracting from heterogeneity and incomplete markets was the lack of dynamic tools to solve such models. Heathcote et al. (2009) Over the past twenty years computational power has increased substantially and numerous dynamic methods have been developed, thus allowing to solve more complex models. This development is crucial for the modeling of distributions.

Modeling heterogeneity is important for several reasons: precautionary savings as a consequence of idiosyncratic uncertainty increases aggregate savings and, thus, decreases the interest rate Huggett (1993)

[6]This assumption is not restrictive for our purposes since we observe the price in our ex post analysis for the period 1983-2007. Hence, the supply of assets and the observed price suffice to determine the equilibrium asset quantities. This allows us to be agnostic about the price elasticity of asset demand.

5 The Model

In the following section I will present the life-cycle model with durables I use in my analysis. After describing the consumer's problem and the income process, I will I give a brief description of the savings determinants accommodated by the model, which will facilitate the subsequent discussion of the results.

As established above, the baseline model in question is a life-cycle model with an imperfect market structure, which incorporates durables. [7]

5.1 Demographics

There is a continuum of ex ante identical risk averse consumers with a finite time horizon. At age 90 consumers die with certainty, younger consumers between the age of 26 and 90 may die with probability $\pi_j < 1$ at age j.

5.2 Consumer's Problem

Consumption savings decision Consumers derive utility from a durable good d and a non-durable good c. The utility function $U(c, d)$ is strictly increasing in both arguments and strictly concave, with diminishing returns for both arguments and allowed to be non-separable in c and d. The choice-set of assets is restricted to durables d and a one-period bond a. Preferences are assumed to be time separable and future utility is discounted with a constant discount factor β. In each period, after receiving the income y_{ij}, consumers decide on the amount they want to consume in this period c_j and next periods portfolio composition d_{j+1} and the financial risk-free asset a_{j+1} are chosen after receiving the income. Agents then derive utility from consumption and durable services, before the assets pay returns. While the liquid assets return an interest rate r durables depreciate at rate δ. This implies the following budget constraint:

$$a_{j+1} + d_{j+1} + c_j = (1 + r)a_j + (1 - \delta)d_j + y_j \tag{1}$$

[7] The present model is a life-cycle version of Hintermaier and Koeniger (2010).

Income Process I directly follow the specification of the income process in Hintermaier and Koeniger (2011). Until retirement every consumer i receives an individual, stochastic labor income y_{ij} in each period. After the age 65 is completed, they retire with certainty and receive deterministic individual-specific retirement benefits b_i.

The authors assume that log of earnings y_{ij} of individual i at age j before retirement is additively separable in a deterministic age polynomial ϕ_j and an idiosyncratic income shock z_{ij}:[8]

$$y_{ij} = \phi_j + z_{ij} \tag{2}$$

,

where the shock z_{ij} follows an AR(1) process

$$z_{ij} = \rho z_{i,j-1} + \epsilon_{ij} \tag{3}$$

Collateral Constraint Durable serve both as consumption good and value storing asset, since their durability implies that they may be used as collateral for short-sales of the liquid asset. It is assumed that all credit needs to be collaterized, either by income or by durable holdings. [9] The collateral constraint takes the form:

$$\underbrace{\mu(1-\delta)d_{i,j+1} + \gamma \underline{y_j}}_{collateral} \geq -(1+r)a_{i,j+1} \tag{4}$$

where $\underline{y_j}$ is the minimum labor income realization across all states in each period and $\mu \in [0,1) and \gamma \in [0,1)$ are the respective fractions of the durable stock and of minimum labor income, which can be collateralized. The timing assumptions made above imply that this constraint guarantees full repayment by consumers and thus acts as non-bankruptcy constraint.[10] $\gamma \underline{y_j}$ can be interpreted as debts where the wage plays a major part in the risk assessment from the lender's side i.e. credit card debts or short-term unsecured loans.

[8]This approach is quite standard in the literature (see others! NEWERS THAN YANG AND KAPLAN VIOLANTE)

[9]As (Hintermaier and Koeniger, 2010) point out, this assumption is reasonable since about 85% of household debt in the SCF 2004 is secured by collateral.

[10]This is assured by the fact, that the lender does know the financial portfolio choice (a_{j+1}, d_{j+1}) and the minimum of the support of the income distribution for all ages, but does not know the realization of future income shocks.$\underline{y_j}$.

(ASSUMPTIONS DO NOT MAKE SENSE!!!)

Net-Worth in the model Net-worth is defined as:

$$x_{i,j} \equiv (1+r)a_{,ij} + (1-\delta)d_{i,j}, \tag{5}$$

And thus reflects the total amount of assets a consumer has access to in a given period.

5.3 The recursive formulation of the household problem

We let T^r denote the first period of retirement. The Bellman equation prior to retirement, if $j < T^r$thus is:

$$v_{i,j}(x_j, d_{i,j}, y_{i,j}) = \max_{a_{i,j+1}, d_{i,j+1}} \left[U(\underbrace{x_{i,j} + y_{i,j} - a_{i,j+1} - d_{i,j+1}}_{c_{i,j}}, d_{i,j}) + \hat{v}_{i,j}(x_{i,j+1}, d_{i,j+1}, y_{i,j}) \right] \tag{6}$$

where the expected next period value function is discouted by the product of the probability of survival $(1-\pi_j)$ and the discount factor β

$$\hat{v}_{i,j}(x_{i,j+1}, d_{i,j+1}, y_{i,j}a \equiv \beta(1-\pi_j)E_j v_{i,j+1}(x_{i,j+1}, d_{i,j+1}, y_{i,j+1}),^{11} \tag{7}$$

with the constraints: (NOTE BORROWING CONSTRAINT NEEDS TO MAKE SENSE!!!! WITH NET WORTH OR NOT????)

$$a_{i,j+1} + d_{i,j+1} + c_{i,j} = x_{i,j} + y_{i,j}, \tag{8}$$

$$x_{i,j+1} = (1+r)a_{i,j+1} + (1-\delta)d_{i,j+1}, \tag{9}$$

$$x_{i,j+1} \geq -\gamma \underline{y_j} + (1-\mu)(1-\delta)d_{j+1}, \tag{10}$$

(WHAT HAPPENS WITH MIN Y IN RETIREMENT????)

$$d_{i,j+1} \geq d_{min}, \tag{11}$$

CHECK THE PART OF INCOME THAT CAN BE USED TO ACQUIRE DEBT!!!!!!!!!!!!!!!!!!!!!!!!!!

After retirement, for periods $j \geq T^r$, the income y_{ij} is given by $b(z_{i,T^r})$, the retirement benefits b depending on the last realization of labor income before retirement z_{i,T^r}.

5.4 Equilibrium Concept

The interest rate is fixed, assuming that changes in the domestic supply of assets do not affect the economy. This assumption corresponds to a small open economy. Moreover, as the price is observed in the ex-post analysis it suffices to determine the equilibrium asset quantities (Hintermaier and Koeniger, 2011). Furthermore, it is assumed that the assets of agents, who dye are taxed away and that equilibrium feedbacks from the government budget constraint are negligible. (ARE THESE ASSUMPTIONS REASONABLE???)

5.5 Motivation

There are a variety of characteristics of this model that demonstrate the its suitability for the analysis at hand. The limited variety of assets implies an incomplete market structure, which hinders consumers to perfectly diversify away the idiosyncratic risk from income uncertainty. The ex-ante identical consumers thus will thus, depending on their income trajectory, end up with different portfolios of the endogenous state variables. Moreover, the optimal decision will depend on the consumers age. The model is therefore well suited to match net-worth distributional facts introduced above, as well as differences across ages.

5.6 The determinants of savings

(IN THE BEGINNING: WHEN I REFER TO SAVINGS I MEAN THE POSITIVE ACCUMULATION OF NET WORTH)

The model presented above accommodates several determinants of savings, the accumulation of net-worth, which I will briefly outline here. These will be further discussed in the subsequent analysis.

Income Risk Agents accumulate buffer stocks of savings in order to self-insure against labor income uncertainty and being able to smooth consumption across different states of the income process. The risk is captured by the AR(1) process specified by Equation 3 and thus depends on the distribution of the error term of the process in question as well as the persistence factor.

Aiyagari (1994) quantifies the aggregate importance of buffer stock savings. (Gourinchas and Parker, 2002) assess the relative importance of these precautionary savings across the life-cycle of a consumer. They show that the precautionary motive dominates the accumulation of savings early in life, while later in life, after the age of 40, savings, due to deterministic changes in income, become more important.

Income growth In the model above there are two sources for deterministic changes in income growth, which give rise to life-cycle savings motives. Firstly, for the working population it is the experience premium, the deterministic age polynomial in Equation 2. Secondly, every household retires at 65 and experiences a large drop in income. These factors together make up for a hump shaped income profile displayed in Figure 2 in Section 8.

The characteristic of these changes is, that they are perfectly anticipated by the consumers. An expected higher income causes perfectly rational consumers to reduce their present savings and increase consumption as they seek to smooth consumption across their life-cycle. On the contrary, when facing a large drop, such as retirement, consumers increase present saving.

Borrowing Constraint Another important determinant of savings in these models is the borrowing constraint. A tighter constraint limits the insurance potential of assets. They limit agents in their ability to short-sell assets and thus trade-off future consumption against present consumption.

Hintermaier and Koeniger (2011) estimate the borrowing limit to be zero for the observed distribution of net-worth in the present paper. Using the definition of net-worth from Equation 4 the borrowing constraint from Equation 4 can be reformulated in terms of durable holdings and net-worth:

$$x_{i,j} \geq -\gamma \underline{y} + (1-\mu)(1-\delta)d_{i,j} \tag{12}$$

implying that in each period net-worth needs to be larger than the negative value of the minimum fraction of income that can be collateralized and the fraction of wealth which cannot be used as collateral. As I will show further below, the calibration implies that although allowing for negative values of net-worth, these are negligibly small and thus similar to Hintermaier and Koeniger (2011).

As introduced above, an important distinction between a more standard specification of the borrowing constraint is that the present constraint is endogenous, since durables can be collateralized. Although, the limit for net-worth may be similar, the collateral value of durables still allows agents to smooth consumption. In an ad hoc specification of the the sort used in Hintermaier and Koeniger (2011), does thus imply a more rigid constraint leading borrowing constrained consumers to reduce present consumption and increasing mean borrowing. This may bias the accumulation of savings early in life, when mean income is quite low. [12]

The role of durables as collateral value further implies that the Loan-to-Value (LTV) ratio is a further determinant of savings. A higher LTV ratio relaxes the constraint and thus allows for more borrowing.[13] I will discuss the effect of changes in the LTV further below. Finally, the relative price of durables is also important.

The relative price of durables (FernÃ¡ndez-Villaverde and Krueger, 2011) shows that the dual role of durables leads to a higher dispersion in net-worth due to the formers relative price. High-income earners are able to accumulate more durables, as these increase, their relative price decreases and financial assets become more attractive. This effect then increases the dispersion in net-worth between poor and rich consumers.

(NOTE THAT MIN Y NEEDS TO BE CORRECTED EVERYWHERE)

[12] See for example FernÃ¡ndez-Villaverde and Krueger (2011), who compare an ad hoc constraint, with limit zero to a version that allows the use of durables as collateral.

[13] Cho (2012) show that changes in the LTV ratio can account for 40% of the difference in homeownership between Korea and the US.

6 Calibration

The calibration strategy demands to be in line with the aim of the paper - discussing the importance of modeling durables in context of the distribution of net worth. It is thus crucial to satisfy a high degree of comparability with other work dealing with net-worth distributions. Moreover, the calibration ought to replicate some features of the data, without containing to much information on the features the model is asked to show. (CITE SOME BOOK/ PAPER). In order to give insight on the underlying parameters of the cross-section of inequality I will thus proceed in the following way. As discussed above, I base the parametrisation of model on Hintermaier and Koeniger (2011) and apply the algorithm introduced by Hintermaier and Koeniger (2010) to solve the model with durables.

6.1 The income process

As discussed above the income process is an important driver of the accumulation of savings as both the income growth and income risk influence a consumer's capital stock along the life-cycle. Its calibration does thus decisively influence the outcome. Hintermaier and Koeniger (2011) use the SCF cross sections to construct a measure for labor earnings risk before retirement purging labor earnings from age effects for consumers between age 26 and age 65.

After retirement the income process is deterministic. Thus, each individual receives retirement benefits from social security, the level of which is determined by the last period's income resulting in a replacement ratio of benefits over gross income of 52% for the median income in the last period before retirement. The approximation takes into account the US social security legislation(http://www.ssa.gov). [14] The age polynomial ϕ_j is obtained by regression the log of earnings on a quartic age polynomial in each survey year of the SCF data between ages 26 and 65.[15] The standard deviation obtained of the residuals resulting from this regression are used to calibrate the distribution of earnings shocks z_{ij}, with the assumption that the shocks are drawn from a normal distribution.

[14] For a detailed description of the cunstruction of these benefits see Hintermaier and Koeniger (2011).
[15] The table in appendix A displays the experience obtained by Hintermaier and Koeniger (2011).

Assuming normality of the error terms the authors found a variance of 0.607 for the 2004 data – $z_{2004} \sim \mathcal{N}(0, 0.607)$. (POSSIBLY COMPARE THIS RISK TO OTHER STUDIES ALSO SEE KRUEGER AND PERRI 2006) The calculations for the experience premium displays a concave relationship between the base age and the rising age it is compared to. Moreover, the experience premium has risen since the 1980s. The autocorrelation of the log-earnings shocks are calibrates as $\rho = 0.95$, which implies a variance for the innovations of $\epsilon_{ij} = 0.048$. (HERE ALSO COMPARE TO OTHER, MORE RECENT LITERATURE) The AR(1) process for z_{ij} is then approximated by a Markov chain with 21 income states via the Rouwenhorst method.

Finally, the authors adjust for growth in life-cycle income to convert the cross-sectional age-earnings pattern into life-cycle profiles considering a growth factor of $1.015^{age-baseage)}$, where the base age is a reference age to make income units comparable across cohorts of different years.

Controlling for the age distribution is another important determinant for the dynamics!

It is worth noting that the smallest income is larger than 0!!!!

Income Process LOOK AT GOURINCHASandPARKER(2002) AND AT THE ADDAandCOOPER BOOK!

unit root in AR process is not imposed (is something that is debated -> they show that their results are not very sensitive toward this issue -> increase ρ toward unity (LOOK AT STORESLETTEN ET AL: (2001) -> do not reject unit root.

6.2 Utility parameters

I consider a utility function that is non-separable in durable- and non-durable consumption, strictly increasing in both consumption types, strictly concave and obeying the INADA-Conditions with respect to nondurable consumption. It is the same class of preferences as Hintermaier and Koeniger (2010), which is commonly used in the literature considering durable and non-durable consumption (CITE MORE). [16]

$$U(c, d) = \frac{\psi(c, d)^{1-\sigma} - 1}{1 - \sigma} \quad \text{where} \quad \psi(c, d) = c^{\theta}(d + \epsilon_d)^{1-\theta}, \tag{13}$$

where I assume $\epsilon_d > 0$, which thus indicates a number small enough to be irrelevant for the quantitative exercise at hand but nonetheless larger than zero. The CRRA utility function with the Cobb-Douglas specification of the consumption index, thus allows for zero consumption of durables, while the INADA-Condition ensures that people always consume some non-durables, i.e. intuitively this means consumers cannot survive without food, but are allowed to survive without houses and cars.[17] (WHAT IS THE CONSEQUENCE OF OMITTING THE EPSILON????

(FernÃ¡ndez-Villaverde and Krueger, 2011) utility form death is normalized to 0 ??????????

The risk-aversion σ typically takes values from 1-5 in the literature (Yang, 2009). Following the aforementioned author I use $\sigma = 1.5$ as estimated by Attanasio, Banks, Meghir, and Weber (1999) and Gourinchas and Parker (2002) from consumption data. The discount factor β and the weight on non-durable consumption θ are calibrated to match the average net-worth holding and average durable holding of the prime age population up to the 90th percentile, respectively. The data moments are 2.95 for the durable holdings and 2.39 for the net-worth in terms of median labor-income. TO MATCH HOW EXACT: SHOW WITH SMALL TABLE (BE CAREFUL TO BE SPECIFIC ENOUGH!) To calibrate the two parameters I solved the for a grid of (??????) for θ and a grid of (???????) for β. The choice to match the 90th percentile and the population from 26 to 55 years old is motivated by the fact that calibrating the model for the whole data-set would lead to overestimating the net-worth holdings of the prime sample –as is both the population above 55 years of age and above the 90th percentile hold more wealth on average than in the prime age sample. The estimation procedure is explained in more detail in appendix B.

(BE MINDFUL OF THE FACT THAT HINTERMAIER 2016 HAS 0.76 FOR HOUS-

[16] Note that this choice is in line with a more generic formulation of the utility function (FernÃ¡ndez-Villaverde and Krueger, 2011).

[17] For the recursive problem it means that when allowing the potentially optimal choice $d' = d_{min}$, the constraint for minimal durable holdings needs to be accounted for explicitly, as the INADA-Conditions do not implicitly exclude zero durable consumption.

Table 2: This table depicts the parameter estimates matching the average durable holdings and average total worth of the prime age population in the data.

Parameters	Baseline	Alternative
β	0.991	??
θ	0.761	???

ING - SAME SAMPLE!!!!!!) The estimation results are somewhat different from what other authors with similar models have obtained. (NOTE DIFFERENCE INF HORIZON AND LIFE CYCLE) FernÃ¡ndez-Villaverde and Krueger (2011) estimate a weight on non-durable consumption of 0.81, Yang (2009) 0.8615 and Hintermaier and Koeniger (2010) 0.8092. (CITE NEWER STUDIES) Whereas studies solely considering housing, obtain estimates more closely to mine (CITE THESE STUDIES). This should, however, not be surprising, as I used data moments which correspond to the means of the above defined prime-age sample, contrary to these other studies, who calibrated their to the whole sample. Díaz and Luengo-Prado (2010) among others, show that the empirical portfolio composition changes over life-time, as will be discussed more in detail below. Young households take on credit to invest in durables and older households accumulate assets to finance retirement. The fraction of durables of total wealth, as the two data moments show 2.95/2.39 is larger than one for the prime-age sample, since the average liquid assets are negative. Where as for the whole sample the fraction of average durable holdings in terms of average total wealth 4.45/6.33 is smaller than one (Hintermaier and Koeniger, 2010). The estimated discount factorβ is quite similar to the one inHintermaier and Koeniger (2011).

6.3 Initial Conditions

In order to properly estimate the model, the specification of the initial conditions is important in a life-cycle model. I follow Hintermaier and Koeniger (2011) (BE MORE SPECIFIC. DO DATA PART!) and construct the initial level of durables via the 24 year old and 25 year old. Appendix D shows the importance of a solid specification of the initial conditions. I re-estimated the model for different specifications of the initial conditions using the initial conditions provided by Hintermaier and Koeniger (2011), which only indicate net-worth. I assigned all net-worth to durables in a first estimation and then to liquid assets in a second estimation. The results show, that the assumption that the initial net-worth can be attributed to durables is sufficient, since the differences between the baseline case and this case are negligible. However, the baseline case still slightly performs better.

6.4 Further inputs

As is common in the literature dealing with the period of the great moderation and supported by empirical evidence, the interest rate r is set to 4%. (CITING LITERATURE). As discussed above, this partial equilibrium approach entails the assumption of a small open economy. Furthermore, I set the loan-to-value ratio $\mu = 0.8$. Although commonly used in the literature, this is a rather conservative assumption for the loan-to-value ratio: CAPLIN ET AL (1997) claim that it is almost impossible for a hh to obtain a house without paying at least 10%, moreover (OTHER AUTHOR IN HINTERMAIER2010 max LTV). However, this will allow me to investigate the effects of recent years, which lead to a relaxation of the LTV (IacovielloandPavan 2013) or (THAT OTHER PAPER ABOUT THE DENSITIES OF LTV). Finally, as in Hintermaier and Koeniger (2010) $\gamma = 0.97$ is chosen to be smaller than 1 in order to assure positive consumption at the smallest gridpoint of next periods net-worth x'. The probabilities of death as in Hintermaier and Koeniger (2011) are taken from Table 1 of the decennial life tables 1979-1982 and 1999-2001 for the calibration of 1983 and 2004, respectively.[18] (COMMENT ON WHY THESE ARE IMPORTANT!)

7 Numerical algorithm

The problem above does not provide a closed-form solution (CITE!!!!) and thus the solution has to be approximated numerically. Hintermaier and Koeniger (2010) offer a solution for problems of this type. They expand the endogenous gridpoints method (EGM) proposed by Carroll (2006) for a problem with two states and thus providing a very efficient algorithm to solve models with durables and collateralized debt. As their

[18]They are published by the National Center for Health Statistics at $http://www.cdc.gov/nchs/products/life_tables.htm$.

algorithm is formulated recursively, it is well suited to solve life-cycle models. [19] I iterate over the policy function starting in period $j = T$ where the consumer sells all liquid assets and durables (TIME ASSUMPTION OF DURABLES IS IMPORTANT HERE - agents retrieve utility from the durable stock before it is sold, and can consume afterwards????) to consume them before death. It thus holds that $x' = d' = a' = 0$ and thus the initial consumption policy is $c(x, d_j, y_{kj}) = x + y_{j,k}$ (NOTE CASE WITHOUT ADC). Each iteration n on the policy function then gives the the solution for the period $T - n$, where in my case $n = 65$ which corresponds to ages 90 to 26.
The exogenous grids for d and x are chosen as follows:

For each period t < T-1, the algorithm proceeds as follows. In a first step it maps x' into d' and in a second step it solves for the current choice c and state x from optimal future combinations (x',d'). Moreover, the values for the exogenous grid are chosen such that the results are not affected. (BE MORE PRECISE INDICATE DIFFERENCES BETWEEN POST/PRE RETIREMENT (expectation)!

7.0.1 Comparing the simulation output with SCF data

Data (Initializing DATA + probability of death (PLOT!)

8 Life-Cycle Profiles

SEEE DOTSEY ET AL FOR THE DATA!!!!

As discussed above, the choice of a life-cycle model is mainly motivated by the fact, that age plays an important role in questions related to wealth distribution and in particular to the net-wealth distribution. This section will give insight into the accumulation of wealth by agents over their lifetime. As we will see, this also affects consumption. FernÃ¡ndez-Villaverde and Krueger (2011) have pointed out that it is paramount to consider durables in order to properly model the life-cycle profile of consumption, which is hump shaped. The authors underline the importance of modeling durables in order to accurately reproduce the the shape of consumption over the life cycle observed in the data.

[19] Solving such models has been considered particluarly expensive and challenging, as durables enter as additional state (if non-separability utility from durables and non-durable or adjustemnt costs are allowed for) and durables increase the dimensionality of the portfolio choice.(Hintermaier and Koeniger, 2010)

He shows that including durables in a non-separable way in the utility function into the canonical incomplete markets model with one asset may achieve a better representation of the hump shape. Namely, durables account for 50% of the hump size, while the other half is attributed to changes in the household size, a fact pointed out by Attanasio et al. (1999). The first section discusses empirical results as well as life-cycle profiles produced by models from theoretical research. In the second section I will produce and comment on the life-cycle profile of my baseline model and then go over to a more detailed investigation of certain factors in the third section.

LOOK AT GOURINCHASandPARKER(2002) for more insight

It's importance is therefore of small magnitude for the present analysis. As discussed above, I focus on consumers aged 26 to 55, where the income process is the main driver of the income risk.

8.1 Life-Cycle profiles in the data and theoretical literature

This section discusses a number of important issues discussed by the theoretical literature related to empirical patterns. I thereby focus on issues discussed in relation to durables.

8.1.1 Consumption smoothing

The standrad life-cycle model with complete financial markets predicts, that individuals smooth consumption over their lifetimes and across states of the world.[20] This is true if the one period utility function and the time discount factor are constant. As households will then choose consumption plans in order to equate marginal utility across time and states of the world. Potentially they might do this with some growth rate, depending on the relative size of the real interst rate and the discount factor. (COPY PASTE (FernÃ¡ndez-Villaverde and Krueger, 2011): "Under CRRA (Constant Relative Risk Aversion), period utility consumption growth itself should be constant across time. With complete markets, consumption smoothing can be achieved through the transfer of contingent claims across periods and states. (this statement relies on the further assumption that leisure and con-

[20]NEED TO FIND GOOD REFERENCES!!! SEE also: Further empirical literature about the life-cycle profile of consumption observed in cross-sectional micro data: Blundell et al. (1994), Attanasio and Browning (1995), Attanasio and Weber (1995), Gourinchas and Parker (2002).

sumption are separable in the period utility function.") However, the data shows that consumption of both, non-durables and durables, is hump shaped over the life-cycle.[21] (amongst others CITE MORE). As these authors point out it is important, especially for policy considerations, such as social security reforms, public provision of saving incentives, or welfare consequences of progressive taxation, as these will vary by age group. FernÃ¡ndez-Villaverde and Krueger (2011) show that 50% of the consumption hump can be accounted for by adjustment through family size. However, the other 50% can only be explained by including durables. Namely, if the period utility function is separable in nondurable consumption and durable consumption, the real interst rate will be equal to the time discount factor and remain constant over time. It thus follows that optimizing households will buy the desired stock of durables early in life and then only replace depreciation from there on. However, as the data shows, durable consumption is hump shaped, which is consistent with work, which has documented liquidity constraints in the purchases of consumption durables [22] or argued that is vital to consider nonseparabilities in the utility function [23].

In this first section, FernÃ¡ndez-Villaverde and Krueger (2011) thus contradict Blundell et al. (1994), Attanasio and Browning (1995) and Attanasio et al. (1999), who argue that if one adjusted the consumption data for changes in household size (which is also hump-shaped over the life-cycle) the hump in life cycle consumption disappears.

Income tracking consumption (COPY PASTE :Deaton (1992) provides an overview for the literature answering this question. The main stylized fact emerging in this literature was that consumption seems to track income over the life cycle, changing only when income changes and not when it becomes known that income will change, as economic theory predicts. was interpreted as indication for liquidity constraints or other financial market imperfections. The empirical observation that consumption initially underresponds to income shocks and then adjusts with a delay. Flavin (1985), Campbell

[21] In the Consumer Expenditure Survey (CEX), when the head of household is 50, the average household spends 63% more when he or she is 25 and 70% more when he or she is 65 (FernÃ¡ndez-Villaverde and Krueger, 2011).

[22] NOTE COPY PASTE FROM FV& K2011 Eberly (1994); Alessie et al. 1997; Barrow and McGranahan (2000); Attanasio et al. (2005)

[23] NOTE COPY PASTE FROM FV& K2011 Attanasio and Weber (1995)

and Deaton (1989), Jappelli and Pistaferri (2010))

8.1.2 Portfolio Composition

As FernÃ¡ndez-Villaverde and Krueger (2011) point out households' portfolio composition do vary over the lifetime. Young households only little liquid assets and hold most of their wealth in consumer durables, whereas later in life, they accumulate big amounts of financial assets to save up for retirement. Durables make up 35%of the aggregate composition of wealth, while equity only accounts for 28% (FernÃ¡ndez-Villaverde and Krueger, 2011).The same authors thus show that these facts can better be accounted for, when one considers liquid assets and durables separately, instead of combining them in one asset such as net worth. The interaction of the two assets thus is able to reproduce the abserved pattern in the data. Where the consumer durables provide both consumption and collateral services as well as an endogenous borrowing constraint.

8.2 Profiles predicted by the model

NOTE THE NUMBERS AND FIGURES NEED TO BE ADJUSTED SINCE THERE WERE SOME OBSERVATIONS DROPPED TO CALCULATE THESE PROFILES!!!!!

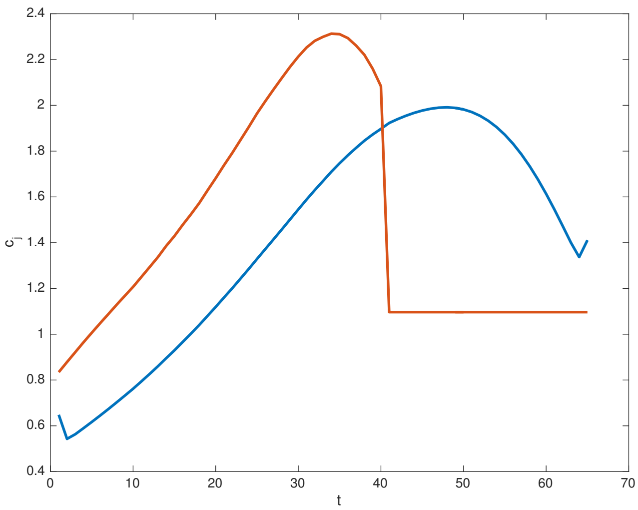
In the following section I will discuss the baseline life-cycle profiles produced by the model more in detail and compare it to other work and empirical results presented therein. I will mainly focus on two aspects discussed in the literature. The consumption and income profiles and comparing the asset profiles, which entails a discussion about portfolio allocations over the life-cycle.

The life-cycle presented in figure 2 and figure 3 show averages of the variables of interest over the simulated population of 100000 consumers aged between 26 and 90. With the exception of net-labor earnings all variables are in units of average net-labor earnings per adult-equivalent. (BE MORE PRECISE HERE)

8.3 Income and Consumption

Income Figure 2 shows the hump of the income profile arising by construction as the process is determined exogenously. Note that this hump shaped profile arises from the experience premium captured by the estimated age polynomial as well as economic growth, up to age 65. Consumers earnings rise until the age of 49, when they reach the maximum log net-income equivalent of 2.3131. Afterwards the experience premium decreases, as the experience factor is dominated by a decrease in productivity to the age of 65, where consumers earn 2.0834, thus around 10% less than when they are at their top. At this point the average income decreases sharply, as every consumer retires after the age of 65 and receives deterministic retirement benefits from then on, with an average of 1.0966. [24]

Figure 2: Average Income and Consumption over the Life-Cycle



Consumption is in terms of average net labor-earning equivalents and and the labor earnings are as calibrated, the log of net labor earnings-equivalents?????? JUST VERY STANDARD! NEEDS TO BE UPDATED

Consumption As income consumption is hump shaped and seems to follow the behavior of income with a slight time lag and its decrease is smooth. Non-durable consumption peaks on average at the age of 74. At that point agents consume 1.9911 in terms of the average net labor-earnings equivalent, which is almost four times as much as at the age of 27, when their non-durable consumption is lowest. [25]

Clearly, agents do not achieve perfect consumption smoothing over their life-cycle. Instead, their consumption depends on other factors. The first observation, consumption traking income, is due to borrowing constraints. In principle, agent's expected future income rises with certainty, due to the higher experience premium. Thus, they would

[24] Following Hintermaier and Koeniger (2011) the growth adjustment is neglected for the retirement period, therefore the curve does not increase for ages 66 to 90. (CHECK IF WOULD HAVE AN EFFECT! OR IS THERE A REASON FOR THIS???)

[25] Note this first fall of consumption is due to adaptation from initiating durables and net worth.

like to accumulate debt early in live to substitute future higher income for todays lower income. In the beginning of their live, as their durable stock is low, and thus the borrowing constraint is tight. Consumption does therefore quite closely track the deterministic, averaged part of the income early in live. [26]As they grow older accumulating a stock of durables, the constraint loosens and agents may borrow more, which facilitates consumption smoothing thus permitting consumption to behave contrarily to income.

As discussed above, (FernÃ¡ndez-Villaverde and Krueger, 2011) show, dourables contribute to a large extend to this hump shape of consumption. The double role of durables, which provides consumption services and may be utilized to substitute wealth across periods, as well as the non-separability of durable and non-durable consumption are responsible for this behavior. In the early part of life consumers prefer to stack durables over consuming more non-durables as marginal utilities are similar, however durables may be used as collateral and itself provides the benefits of investment. The non-separability is responsible for a rise in non-durable consumption as the early increase in durables decreases the latters marginal utility and thus the relative utility benefits of consumption rises as agents grow older.
Later in live, when death becomes more likely and utility is discounted to a larger extend consumption decreases again. [27]

Comparing to results reported in the literature FernÃ¡ndez-Villaverde and Krueger (2011) and Yang (2009) have looked at life-cycle profiles using very similar models. They both find similar shapes. However, differing in the size and period of the peak. Using data from the Consumer expenditure survey (CEX) and correcting it for the family size, FernÃ¡ndez-Villaverde and Krueger (2011) show that the average household spends 65% more than when the head of the household is 50 compared to when he or she is 25 and around 70% more, when he or she is 65.[28] Their model predicts a peak around the

[26]this model does display excess sensitivity of consumption to income (income tracking consumption to closely SEE LITERATURE!!!!), which contradicts the predictions of the basic life-cycle model.See DEATON (1992) for a review

[27]The late rise in consumption is due to life-time uncertainty. As consumers are never entirely sure at what point they will die, they hold a small buffer even when retired and subject to deterministic income. In the last period, they die with certainty and thus sell all of their assets increasing consumption.

[28]FernÃ¡ndez-Villaverde and Krueger (2011) use data from 1998. Yang (2009) reports similar findings for estimating consumption profiles from CEX 2001 data. Adjusting for household size, he finds an peak at age 55, with an increase of roughly 60% compared to age 20.

age of 45, with a size that is about 40% bigger than at the age of 20. Yang (2009) reports similar results: non-housing consumption at age 50, where it peaks, is 80% more than that of age 20, after the peak, the decrease is steady and at age 75, people consume 25% less on average.

Notably, the increase of consumption is much higher than reported by other, similar models and the data. Moreover, consumption peeks much later in life. One important difference between the two papers discussed above and my own analysis is the model calibration involving the estimation of preference parameters. As explained above, the estimation of the the discount factor (SURE ABOUT THIS?????) and the weight on non-durable consumption are calibrated to match the prime-age sample, which leads to a lower theta and a higher beta. (SHOW THIS!!!!!!!!!!) (MAYBE ANALYSIS WITH POLICY FUNCTIONS!!!) Trading off durable and non-durable consumption has a lot to do with the discount factor!!!!

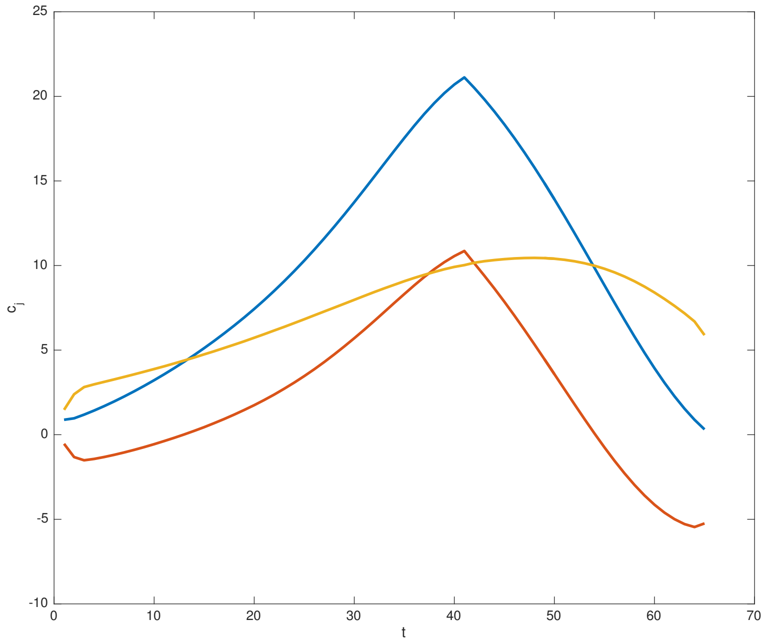
8.4 Portfolio Composition over the Life-Cycle

As discussed in the previous section, average non-durable consumption over the life-cycle is influenced by the capacity to accumulate assets as well as the choice of asset accumulation. The present section discusses the average portfolio composition over the life-cycle.

Wealth Portfolio All three curves display humps. Liquid assets and net-worth peak at age 66, the period when consumers retire and durables peak at 73, exhibiting a later and somewhat slower decline.

Early on in live households borrow as much as possible to accumulate durables, which leads to a sharp rise in the average durable stock early on in live. Savings in liquid assets thus start out to be negative and then rise as consumers start to save up for retirement. As durables can also be used to insure against idiosyncratic shocks, assets are primarily used for life-cycle purposes. Moreover, assets only become relatively more interesting as the average stock of durables rises and its marginal utility, the return on durables, shrinks, while the interest rate is fixed.

Figure 3: Average Asset Holdings over the Life-Cycle



NEED TO INDICATE THE MEASURES. JUST VERY STANDARD! NEEDS TO BE UPDATED

What does the literature say? Yang (2009) documents life-cycles for net worth, housing stock and non-housing assets controlling for cohort and time effects by constructing synthetic sohorts by using six waves of the SCF (1983-1998). [29]. He shows that housing value increases until age sixty-five and then flattens out until the end of the life cycle. [30] Moreover, he shows that young agents tend to hold little wealth, borrowing early in life to buy houses and once they have accumulated stocks of houses start to save in financial assets. Financial assets surpass housing assets in the early 40ies. Moreover, net-worth and liquid assets peak at the age of 70 and then stay constant until the end of life.

While the model captures the between durables and financial assets quite well and predicts the timing of the peaks in a reasonable manner, two factors are at odds. Durables, seem to be favored to an extend not found in the data (LOOK FOR A BETTER WAY TO DESCRIBE THIS!) and in the model, all assets decline again. While, the decline in durables may be explained by the data to some extent and only of small magnitude

[29] Details of the estimation are available in Yang (2009)

[30] He shows that in order to achieve this one must model adjustment costs. Otherwise, the key prediction of the standard life-cycle model is that ratio housing stock to non-housing consumption stays constant over time, does arise, which is inaccurate.

(FernÃ¡ndez-Villaverde and Krueger, 2011), liquid assets and net worth decline by a very big margin. Liquid assets become negative again at the age of 80, and net-worth reaches zero at 90, when all agents die with certainty. For the very obvious reason, that agent do not derive utility from leaving any assets behind.

(FernÃ¡ndez-Villaverde and Krueger, 2011) look at data and show that durables rise quite early until around the age of 30 and then peak in the mid-40ies, while declining afterwards.

The model reproduces a few important factors of the life-cycle composition of wealth:

1. (COPY PASTE (FernÃ¡ndez-Villaverde and Krueger, 2011): Young households save and thus net worth becomes positive at the age of 35 (MINE IS NEVER NEGATIVE!!!) but they do not save in financial assets, but rather accumulate consumer durables.

2. As the households get older, they do start accumulating more assets, which are important in retirement. They do hold a lot of net worth until high ages in order to insure against living too long. Elderly households seem to overacumulate assets. (Seems not to be the case in my model!!!)

Figure **??** shows how net net worth evolves over the life-cycle.

Durables Note that the durables are rather different from (FernÃ¡ndez-Villaverde and Krueger, 2011) (COPY PASTE:Consumer durables: the stock follows a hump shape, differing from a complete-markets model where the desired stock is built up in the first period and only an amount equalto depreciation is spent each period thereafter. Comparing durable consumption (model) and durable expenditure (the data): the model generates a pattern of consumer durables that somehow diverges from the observed pattern: there is a big peak in the first years and then it falls, even though it is possible to see something of a hump after the first spike. One possible explanation is that in the data young families obtain bequests, which in large part come as consumer durables. A second possible explanation is the endogenous formation of households in the data. In our model, all households enter their active economic life at age 20, a time period where they want to build up the desired stock of capital. In the data, however, economically active (in the sense of our model) households are created endogenously due to differences in marriage timing and education. This endogeneity smooths out the first big spike of durable expenditures in the data and leads to the pattern of life-cycle durables expenditure reported in section 2. (this divergence between data and model may also indicate that our borrowing constraint is specified too loosely, allowing households to invest in consumer durables at too rapid a pace when young.)

Yang (2009) shows that modelling adjustment costs is important to account for the slow downsizing of durables (housing in his case) as agents get older.Since the high transaction costs for trading houses prevents the households from decreasing their stock quickly later in life. He also shows that when agents are young they build a housing stock and compromise on non-housing consumption. Moreover, as they age they start to decrease non-housing consumption because time the time preference is higher than the interest rate and mortality rates are increasing along the life cycle.

9 What features of the Wealth Distribution are explained by the model?

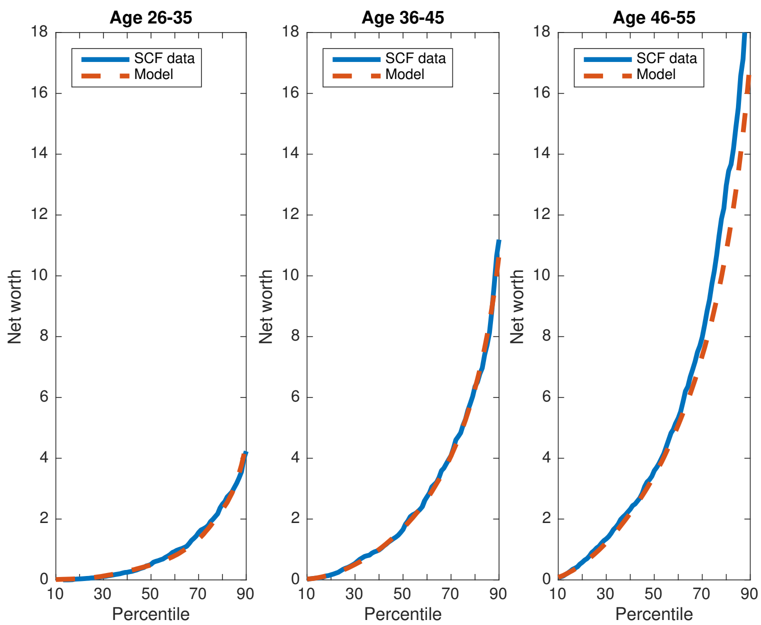
In the previous section we have seen what durables may contribute. Since they do have an impact on life-cycle consumption it seems likely that they will affect the wealth distribution created by the model in one way or the other. In the first part of this chapter I will discuss certain features of the wealth distribution that the baseline model is able to capture. In a second part I will conduct experiments on some parameter changes and analyze how this affects the wealth distribution. Namely, I will drop the adjustment costs, then simulate a model where durables do not provide any utility to provide an insight for the importance of durables. Moreover, I will try different versions of the borrowing constraint, remove the probability of death and finally look at some features of the income process.

9.1 Creating a cross-section from simulated life-cycle profiles

In order to proceed with the distributional analysis and to compare the model distribution to the empirical distribution, the above life-cycle profiles have to be converted into a cross-section. In order to do so I follow Hintermaier and Koeniger (2011), who reproduce the age-composition of the relevant data sample and then account for cohort effects resulting from income growth.[31]

9.2 Model Predictions

Figure 4: Average Durable Holdings over the Life-Cycle



CHANGE THE BLOODY COLOURS!!!! IT IS THE SAME AS IN HINTERMAIERS! NEED TO INDICATE THE MEASURES. JUST VERY STANDARD! NEEDS TO BE UPDATED

Figure 4 shows the net-wealth distribution for three different age groups from the 10th to the 90th percentile. The blue represents the SCF-Data from the year 2004 and the dotted orange line shows the distribution reproduced by the model. Table 3 shows the corresponding gini-indices. The ones for the SCF-Data are directly taken from Hintermaier and Koeniger (2011) whereas the model indices and averages are calculated from the net-wealth distribution resulting from the model simulation.[32] The evidence suggests that the

[31] I hereby use the matlab function, compose_survey.m, provided by Hintermaier and Koeniger (2016).

[32] As I allow for negative net-worth holdings in the model, the gini-indices have to be normalized, as otherwise indices of a magnitude larger than 1 were possible. I hereby follow Chen, Tsaur, and Rhai (1982). Note that this may slightly bias the gini-indices compared to the ones calculated without

model does manage to reproduce a decent representation of the wealth distribution. For the youngest age group it does uderpredict inequality, while for the other two the model does quite accurately reproduce the ginis. While one may argue about the precision it is evident, that it reproduces a known feature (AS DISCUSSED IN THE FACTS PART) of the empirical distribution, namely that while average wealth holdings increase with age, the concentration of wealth holdings decreases. The means are such that the model predicts average net-worth of the younger two age groups quite accurately, however, underpredicts average worth for the oldest age group.

COMPARE RESULTS TO OTHER STUDIES!

Table 3: As Table 6 in Hintermaier and Koeniger (2011) this Table shows the Gini and Means for the distribution of different age groups up to and with the 90th percentile of the net-worth distribution.

	Data	Model
Age 26-35		
Mean	0.80	0.8137
Gini coefficient	0.713	0.6273
Age 36-45		
Mean	2.36	2.3609
Gini coefficient	0.596	0.5850
Age 46-55		
Mean	4.81	4.2821
Gini coefficient	0.564	0.5464

10 Relative degrees of inequality and the overall distribution

So far I have only discussed net-worth in the distribution section. However, the model does also reproduce a distribution of consumption as well as the two assets, which make up net-worth, independently. Moreover, there is the distribution of earnings, which is endogenously determined. It is well known that heterogeneous agent models of this type are able to reproduce the ordinal ranking of inequalities for consumption, income and net-worth in line with empirical evidence.Aiyagari (1994) shows that the model reproduces

normalization. BE MORE PRECISE!!!

Table 4: Gini indices for the different distributions

	Consumption	Income	Durables	Liquid Assets	Net Worth
Model	0.3492	0.4248	0.3611	0.9542	0.6618
Data	????	0.427	0.67	0.97	0.81

empirical plausible relative degrees of inequality, where consumption exhibits the least inequality, followed by income and capital is most unequal.

Table 4 displays the gini indices for the whole distribution produced by the model and the one found in the data.[33] The model manages to match the ordering for the different inequalities considering the types of the assets as well as net-worth. Moreover, it also shows that the consumption inequality is lowest. However, it does not manage to show that durables are more concentrated than income. Díaz and Luengo-Prado (2010) show, in a model with housing, that this may be overcome by explicitly modeling a rental market. [34]Housing makes up the biggest part of durables (CITE AND SHOW NUMBERS). As a consequence of rental markets, wealth poor households will decide to rent instead of owning, thus satisfying their durable consumption needs without being able to benefit from the collateral value of the durable object. As the rented object does not account for the housing part of the durable holdings, wealth poor will hold less durables and thus the gini index of durables increases, while, as Díaz and Luengo-Prado (2010) show, the other indices change only slightly are only marginally affected.

As discussed above, the model cannot predict the net-worth inequality over the whole distribution. This, however, is further encouraged through the fact, that I matched the model to the 90th percentile.

11 The decomposition of determinants

In this section I perform a series of experiments to simulate, how one-time unexpected changes in the determinants introduced above affect both the wealth distributions of the age groups, as well as the life-cycle profiles.

[33]The empirical indices for durables, liquid assets and net worth are taken from Hintermaier and Koeniger (2010) and the index for income from Hintermaier and Koeniger (2011)

[34]

11.1 Loan-to-value ratio

An important determinant, when considering durables is the loan-to value ratio (LTV), which is equal to the part of a durable that is collaterizable. A lower loan to value ratio, would mean that when purchasing a house the amount of credit needed by a consumer would be higher. As is evident, the loan to value ratio has increased by quite a margin during financial libaration. I here simulate the effect of a one time change and unexpected change of the loan to value ratio. A decrease in the LTV to 0.8 (Show increase instead and cite papers. Possible to go over 1?) .

(DO I NEED TO CITE YANG AND DIAZ????) Modeling durables, thus provides the opportunity to model an endogenous specification, where the durables can be used as collateral. Higher durable holdings do therefore loosen the borrowing constraint and enable the consumers to borrow a larger amount of liquid assets.

To some degree, this allows to incorporate changes in the financial liberalization into the model. Díaz and Luengo-Prado (2010) simulate changes in the downpayment rate and investigate how these affect the distribution. Yang (2009) show how these affect the life-cycle. Finally, Cho (2012) assess the importance of the loan-to-value ratio for differences in the wealth distributions between the US and Korea.

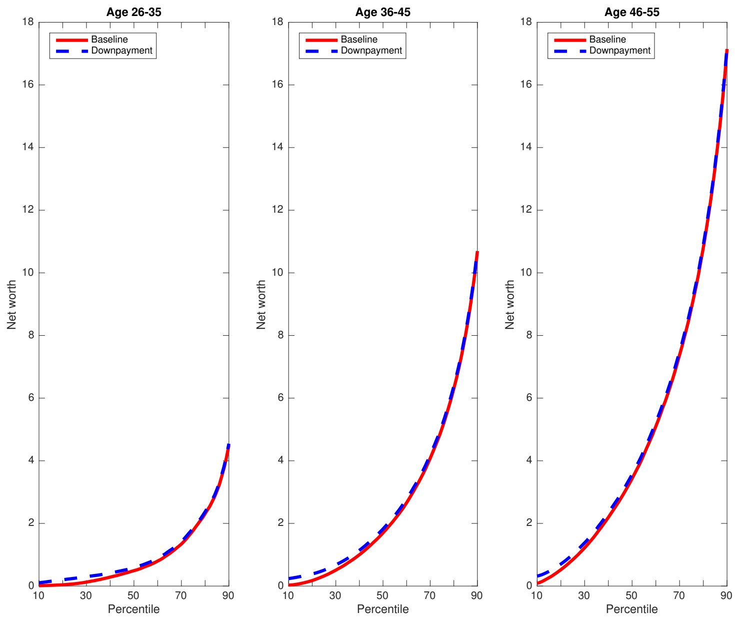
11.1.1 The distribution

Table 5: As in Table 3 this Table shows the Gini and Means for the distribution of different age groups up to and with the 90th percentile of the net-worth distribution for the baseline estimation and the ceteris paribus change of the LTV.

	Baseline ($\mu = 0.97$)	$\mu = 0.8$
Age 26-35		
Mean	0.8137	0.9142
Gini coefficient	0.6273	0.5495
Age 36-45		
Mean	2.3609	2.4976
Gini coefficient	0.5850	0.5447
Age 46-55		
Mean	4.2821	4.4224
Gini coefficient	0.5464	0.5246

Figure 5 shows the impact of such a change on the distributions. The red line represents the results obtained from the baseline calibration and the dotted blue line the steady state distribution for the prime age sample after a change of the LTV ratio. All three age groups seem to be affected. However, only the poorer consumers are affected. With a tighter borrowing constraint, poor agents cannot borrow as much and thus keep more net-assets. This tightening does not affect the rich, who have already accumulated enough assets to borrow at their desired rate.

Figure 5: Average Durable Holdings over the Life-Cycle



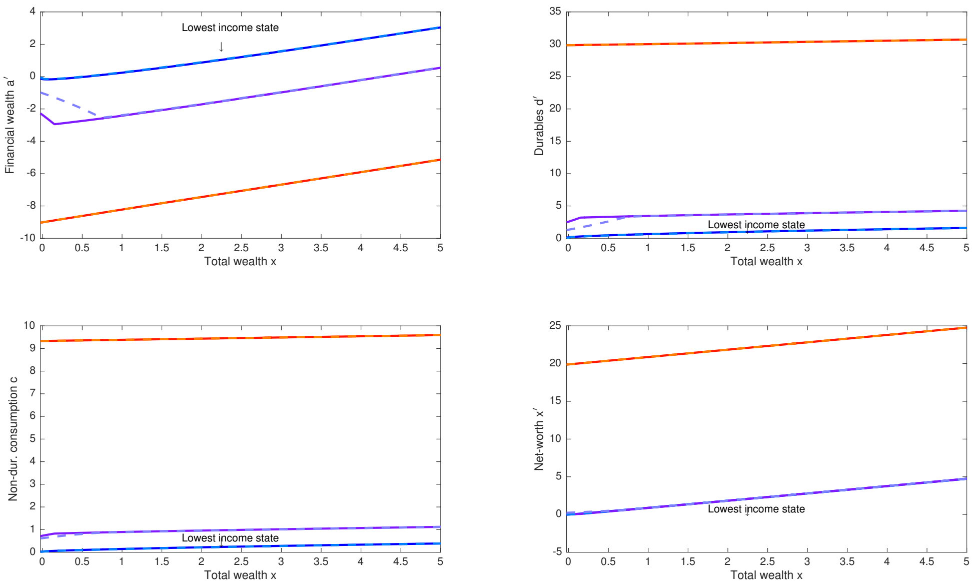
CHANGE THE BLOODY COLOURS!!!! IT IS THE SAME AS IN HINTERMAIERS! NEED TO INDICATE THE MEASURES. JUST VERY STANDARD! NEEDS TO BE UPDATED

Table 5 displays the gini and means estimates of the baseline estimation and the ceteris paribus change of the LTV. A first observation is, that all the means across the age groups rise by an amount of a similar magnitude when lowering the loan-to-value ratio. The means of the older groups rise by a larger magnitude. The second observation is, that all of the ginis drop. Here, however, the heterogeneity is of a more important magnitude. The differences across the age groups is almost gone after the rise in the LTV meaning that the gini drops most for the youngest age group. This is in line with the observation, that tightening the borrowing constraint affects the poor, who are most likely to be borrowing constraint. The medium income is lowest for the young. Moreover, they do not yet have accumulated enough durables to relax the borrowing constraint.

11.1.2 On the individual level

Figure 6 displays the policy functions for a 36 year old agent at three different income levels: the lowest income, the intermediate income and the highest income. As the figure shows, only the 36-year old consumer with an intermediate income is affected and only the very poor 36-years old with this income. Namely the borrowing constraint that are harmed by a tighter constraint. The other agents, the ones with higher income and lower income are not affected, since they are far enough from the constraint or constraint in their borrowing in either case. Note, this case is representative for all age groups. It abstracts from the variety of income levels for illustrative purposes. As the above illustrates, income levels close to the state displayed in the middle display a similar trajectory of optimal choices for the individual agent. These closer to the extreme levels are more likely not to be affected by the change.

Figure 6: Change of the LTV-rate to 0.8

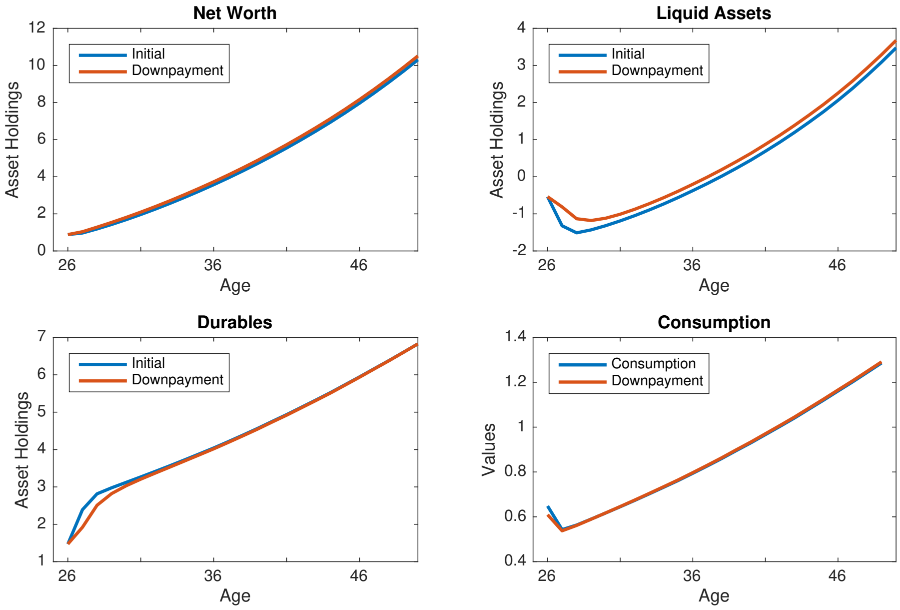


The figure displays the different policy functions for the baseline case, solid-lines vs. the case with a reduced loan-to-value ratio, dashed-lines. The different colors display different wage levels. The blue lines illustrate the highest income, the purple lines are the intermediate income level and the orange lines the lowest income level.

11.1.3 Over the life-cycle

Figure 7 shows how the change affects consumers over the life-cycle. A lower loan to value ratio forces agents to pros-pone the accumulation of durables for a few years. As they now can finance a smaller part with debt, they cannot immediately increase the durable stock but need to accumulate it step by step to be able to increase borrowing. Note that only in the very first period, consumption is affected. It does therefore not affect consumption smoothing??? This trade-off is mainly one, between durables and liquid assets. At around age 30 the durable level is the same as in the baseline case, however, the liquid assets stock stays higher for quite some time and thus net worth is affected over this period.

Figure 7: Average Durable Holdings over the Life-Cycle



CHANGE THE BLOODY COLOURS!!!! IT IS THE SAME AS IN HINTERMAIERS! NEED TO INDICATE THE MEASURES. JUST VERY STANDARD! NEEDS TO BE UPDATED

look at policies!

NOTE SIMULATE OVERBORROWING i.e. a negative downpayment

11.2 The income process

Income risk As discussed above, the volatility of the labor-income is an important feature of the accumulation of wealth. I hereby simulate a change in the risk, by setting the parameter equal to the estimate in 1983. It thus indicates a change of that magnitude. It is well established that the income risk changed over time. Moreover, there is evidence that idiosyncratic income risk changes with business-cycle fluctuations. CITE STORESLETTEN ET AL ETC... THIS PAPER indicates that in the us it is negatively correlated with the business cycle. THE CHANGE IN RISK HERE CORRESPONDS

TO A CHANGE OF MAGNITUDE CORRESPONDING TO.....

The results presented in Table 6 show that a decrease in the volatility leads to lower net-worth holdings across all age-groups. The effect on the ginis does seem to be rather small. However, there are some changes. The distribution across the youngest group shows a rise in inequality. The same can be said for the intermediate age group, although the effect is smaller here. Finally, the change for the last group indicates a drop in inequality.

Table 6: As in Table 3 this Table shows the Gini and Means for the distribution of different age groups up to and with the 90th percentile of the net-worth distribution for the baseline estimation and the ceteris paribus change of the risk (be more precise).

	Baseline	Lower Risk
Age 26-35		
Mean	0.8137	0.7034
Gini coefficient	0.6273	0.6339
Age 36-45		
Mean	2.3609	2.0227
Gini coefficient	0.5850	0.5897
Age 46-55		
Mean	4.2821	3.7679
Gini coefficient	0.5464	0.5420

As a consequence of lower income risk, the agents can reduce precautionary savings. However, the change also affects the mean of the wage. A lower variance in the error-term leads to a lower average income. Low income households are able to increase their durable holdings and thus borrow more and also increase their consumption. They thus save marginally less than before. Middle income consumers are the most interesting ones, the poor behave as the low-income households do. However, the richer ones do increase their asset holdings, and drop durables also dropping consumption to raise net-worth savings. The richest, consume less in durable and non-durables, and borrow more, thus reducing the net-worth stock.

Note, the effect is mainly driven by the high-income households. They, reduce the accumulation of net-worth substantially. As they are young a decrease in all policy functions can be observed. When they get older, they start to marginally increase assets, however, the drop in durables becomes even more substantial leading to a more substantial drop in net-worth. This increase in assets has to do with life-cycle savings. The drastic decrease in both types of consumption does indicate that the drop in income is the dominant force of the impact.

Experience Premium As pointed out in the discussion of the determinants. An important feature of this model is the experience premium. In this section I set the experience premium to zero in order to visualize the impact of a potential change. Hintermaier and Koeniger (2011) show that the experience premium has changed over the years and also.... for a more indebt discussion of the dynamics of the experience premium.

Table 7: As in Table 3 this Table shows the Gini and Means for the distribution of different age groups up to and with the 90th percentile of the net-worth distribution for the baseline estimation and the ceteris paribus change of the experience premium.

	Baseline	No experience premium
Age 26-35		
Mean	0.8137	1.7453
Gini coefficient	0.6273	0.5783
Age 36-45		
Mean	2.3609	4.8234
Gini coefficient	0.5850	0.5114
Age 46-55		
Mean	4.2821	7.0865
Gini coefficient	0.5464	0.4982

Table 7 shows that the means of all age groups dramatically increase. While this increase is most crucial for the first age group, more than 100% this effect is lesser for the older age groups. The gini indices all decrease by a similar magnitude, whereas this decrease is strongest for the second age group.

There are two factors driving this result. The first one is a flatter increase of labor-earnings, they now only grow due to economical growth. The expected future labor income is thus more similar to today's labor income for the working age population. It follows that consumers decrease borrowing, which in turn increases savings. The second factor is a change in average income over the life-cycle. Young consumers do now relatively have a much higher income than before and can therefore adjust their durable stock much faster.

As the policy functions show, one or the other effect may dominate depending on the income level. High-income households do accumulate more net-worth, as they reduce borrowing and increase both durable and non-durable consumption. Medium- and low income households, are borrowing constraint and thus still want to borrow, to increase their durables as quick as possible. Resulting in a slightly negative net-worth for the low income consumer and slightly positive net-worth for the medium income consumer.

As the households age, the positive difference becomes smaller in is close to zero at the age of 55 for the richest household. The large part of the higher savings is thus driven by the high earnings household, who start accumulating more savings early on.

The differences in inequality is mainly driven by the high-earners, but poors, who decrease borrowing and thus net-worth substantially leading to a more equal distribution of assets.

12 Conclusion

The life-cycle model with durables and endogenous borrowing constraints calibrated to match micro-level household data in the US in 2004 is able to match a number of features in the data. It is quite successful in reproducing important features of the wealth distribution, predicting an increase of the average net-worth holding over the life-cycle accompanied by a decreasing inequality in net worth. Moreover, it matches the wealth distribution for the working age population between 26 and 45 quite well. Furthermore, it can replicate the portfolio composition as well as the consumption expenditure along the life-cycle. The endogenous borrowing constraint with durables serving as collateral helps to explain the surge in durable consumption early in live and the increase of liquid assets later in life. Finally, the model can also predict the relative ranking of inequalities. However, I also found that such a parsimonious model has its limits. Namely it under predicts the accumulation of wealth of the oldest age group. These results are rather similar to Hintermaier and Koeniger (2011), who analyse the out of sample prediction of a simpler model specification, without durables, using the same particularization. Calibrating the model to match the 1983 US wealth distribution, they find, that their model manages to predict changes of the younger two age groups. However, they fail to predict the sharp increase in average wealth of the oldest age group. This suggests that the effect reported by (FernÃ¡ndez-Villaverde and Krueger, 2011), where durables increase the dispersion of net-worth between high- and low-earners, is not enough to explain the large increase in average wealth for the last age group. Hintermaier and Koeniger (2011) have argued that this may be due to measurement problems for pension wealth in the SCF-data. Alternatively, this may be due to the abstraction from additional features such as a richer heterogeneity in the earnings process. Guvenen, Karahan, Ozkan, and Song (2015) shows that the log-normality assumption does not hold for higher-oder moments of the individual earnings shocks. They display strong negative skweness and a very high kurtosis, implying that most individuals experience very small shocks and a very small number experiences very high shocks. Moreover, he shows that shocks display very high heterogeneities along the life-cycle. (((COPY PASTE: the authors highlight that earnins changes display substantial negative skewness and kurtosis and that the conditional moments of earnings changes display substantial variation by age and previous earnings level.))) Finally, some heterogeneity in the rates of return may be able to explain the large net-worth holdings for the 46 to 55 years old. Namely, rising rates of returns in wealth. Fagereng, Guiso, Malacrino, and Pistaferri (2016) show evidence for heterogeneities in returns, which are attributed to wealth-holdings but also on an individual level.

as reported by Benhabib et al. (2011) heterogeneity in rates of returns might account for the sharper increase in net-worth. Finally, the bequest motive may have some influence. De Nardi and Yang (2014). It may be interesting to include such features.

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A Experience Premium

Table 8: The annualized experience premium of labor income at ages 36, 46 and 56 relative to age 26.
Source: Corresponds to Table 4 in Hintermaier and Koeniger (2011) and displays the results of the authors' calculation based on SCF Data.

Annualized experience premium		1983	2004
Age –26:	10 years	1.81%	2.60%
	20 years	1.33%	2.18%
	30 years	0.99%	1.83%

B Estimation

Due to my estimation strategy, to estimate the model for the prime age sample and thus excluding consumers, which are situated in the top 10% of the wealth distribution, the means estimation does not suffer from the bias Cagetti (2003) puts forward.

ADDA and COOPER: Model is just identified. Choice of weighting matrix imp when model is overidentified.

The moment condition holds for both moments:

$$E(d_i - D(\beta_0, \theta_0)) = 0$$

$$E(d_i - X(\beta_0, \theta_0)) = 0$$

where D and X are the average of durable stock and net worth holdings of the prime age population respectively. As a consequence, the simulated method of moments can be applied (Duffie and Singleton, 1993).

Therefore I look for

$$\widehat{\Theta} = \arg\min[(m(\Theta) - \nu)' I (m(\Theta) - \nu)]$$

where Θ is a vector containing β and θ, m contains the simulated moments for a specific Θ and $\nu = [2.95, 2.39]$ the empirical counterpart.

$\hat{\beta}$ and $\hat{\theta}$ that

Heathcote et al. (2010): (COPY PASTE: As Christiano and Eichenbaum argue, the exact identification strategy allows for a clear separation between what the model is restricted to match and what it is designed to explain. The exactly identified strategy amounts to a weighting matrix that sets positive and equal weight only on certain moments, based on the investigator's prior about the (first-order) dimensions of the data that the model should fit.)

C Data

D Initial Conditions

I re-estimated the model setting the initial conditions from Hintermaier and Koeniger (2011) in net-worth equal to durable holdings and liquid assets to zero, when simulating the life-cycle profiles. I repeated this process setting net-worth equal to liquid assets and initial durable holdings to zero.

Table 9 depicts the estimation results for the preference paramters θ and β as well as the estimated moments. The table shows that the moments are matched up to a precision 10^{-2} for both cases.

Table 9: This table depicts the parameter estimates matching the average durable holdings and average total worth of the prime age population in the data.

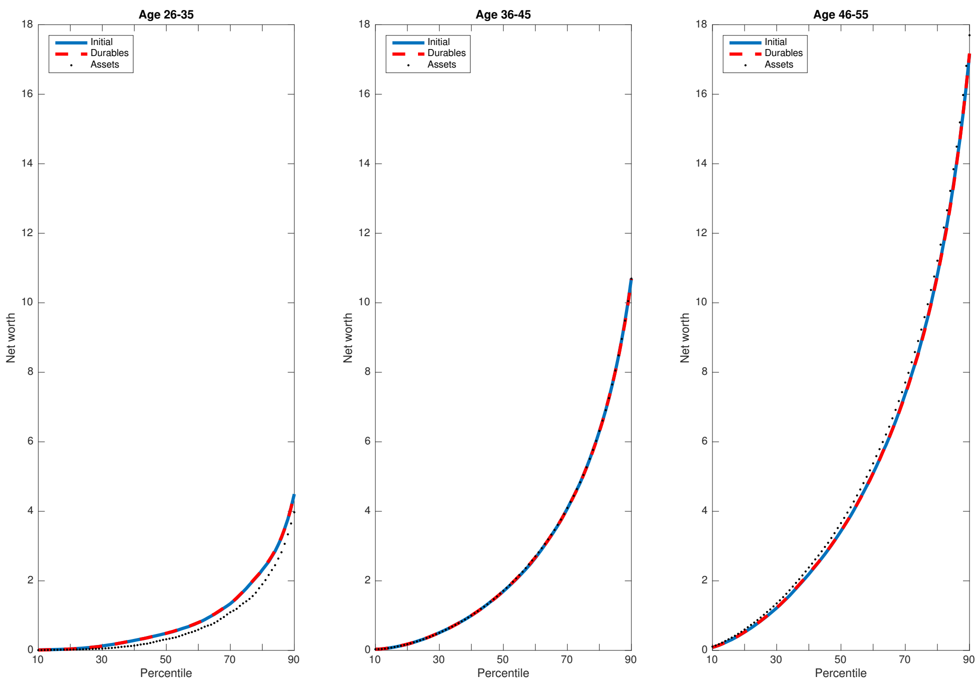
Estimations	β	θ	Av.Durables	Av.Net-Worth
Durables	0.991	0.759	2.9527	2.3906
Assets	0.994	0.749	2.9455	2.3851

Table 10 shows prime age moments for the three different estimations as well as for the data. Attributing the initial net worth entirely to assets produces results that are way off for the youngest age group. The results for the middle age group are matched reasonably well and for the oldest age group they are matched rather badly. Interestingly, when attributing all initial wealth to durables the results are almost the same as for the baseline case. This, however, is not surprising as young households hold almost the entirety of their wealth in durables. Moreover, when performing the different estimations, I abstracted almost from all negative balances of net worth. The assumption, that all positive initial net-worth is durable wealth, would be a sufficient one, for the present model specification.

Table 10: As in Table 3 this Table shows the Gini and Means for the distribution of different age groups up to and with the 90th percentile of the net-worth distribution for the different estimates.

	Data	Baseline	Durables	Assets
Age 26-35				
Mean	0.80	0.8137	0.8170	0.6433
Gini coefficient	0.713	0.6273	0.6281	0.6696
Age 36-45				
Mean	2.36	2.3609	2.3628	2.3705
Gini coefficient	0.596	0.5850	0.5843	0.5845
Age 46-55				
Mean	4.81	4.2821	4.2810	4.4958
Gini coefficient	0.564	0.5464	0.5456	0.5388

Figure 8: Distribution with different initial conditions



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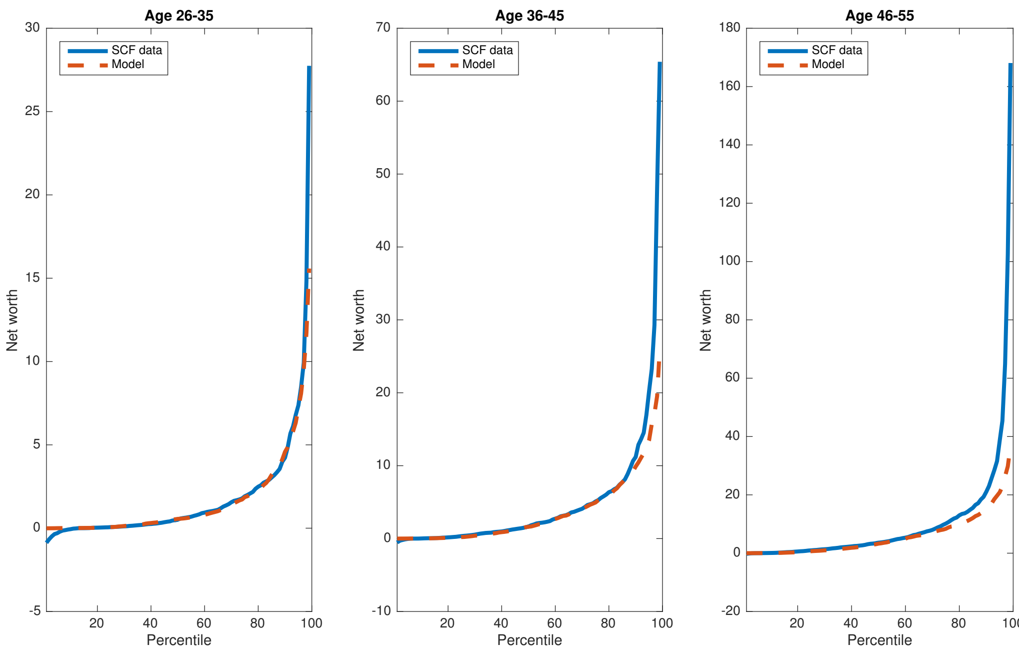
E The full distribution and the issue with the tails of the distribution

Figure 9 shows the full distribution of the three age groups. Note that the scale of the y-axis varies between the age groups and compared to 4 in order to illustrate the whole outline of the empirical distribution. In comparison to the previous graph, two differences immediately meet the eye. For one, the model is not able to correctly predict the lowest part of the distribution. While in the model the poorest agents' net-worth holdings are around 0 for all ages, the SCF-Data displays negative values, which are more pronounced for the two younger generations. The second notable difference is the top of the distribution. Clearly, the model is unable to generate high enough savings for the richest 10%. This is a known problem in the literature.[35]

Figure 9: Average Durable Holdings over the Life-Cycle



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[35]See Fella and De Nardi (2017) for a review and modeling choices that are able to deal with this issue.

The richest One of the reasons is that people in the later stages of their lifes do not have enough incentives to accumulate assets. The main driving forces during their life-cycle is the accumulation of assets for retirement as well as precautionary savings, i.e. to be able to deal with wage shocks. However, as the agent approaches death, the incentive to substitute assets for consumption becomes stronger and stronger. As seen in the life-cycle profiles REFERENCE GRAPH, the point where agents start decumulating liquid assets and durables with 65, when entering the retirement period. There are different ways in dealing with this issue. One approach is to model a bequest motive. Agents will thus draw utility from the capital stock remaining at the time of death and therefore tend to accumulate more and longer over the life-cycle (CITE DE NARDI!). Another way is to model extreme income risk. (Castaneda et al., 2003) calibrates the income process to match the ginis of both the income as well as the net-worth distribution. The resulting income states contain an extreme income state of a magnitude about 100 times larger than the second state and 1000 times larger than the worst state. The issue with this approach is that the income process then is not founded on micro-data of the income, which may be counterproductive for policy recommendation.

MAYBE INCLUDE GRAPH WITH SAVING RATE FROM DE NARDI

The poorest The main reason for the poor reproduction of the lowest 10% is the calibration. When Hintermaier and Koeniger (2011) estimated their preference parameters they did not consider all observation with negative net-worth as their estimation approach did not permit for negative values.