Essays in Household Finance

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I Introduction

Household Finance is a research area at the intersection of economics and finance which aims to understand, predict and provide the right incentives for households' saving and investment behavior. It covers topics from optimal retirement saving to portfolio choice and diversification in the stock market or optimal financing of home purchases. Central to this field is the observation that real household investment behavior is often at odds with the predictions of existing economic models. For example, many people do not invest in stock markets even though standard economic theory suggests that it would be beneficial for them. Another example is that households often fail to refinance their mortgages optimally.[1] To understand household decisions it is therefore important to take possible limitations into account.

There are two sources of potential limitations - informational limitations and behavioral limitations. The first kind of limitations, informational limitations, can either arise because households do not receive full information about the income they can expect in the future, about the behavior and expectations of other market participants, or the state of the world in general. Or, on the other hand, informational limitations can arise because people are simply not able to fully process or understand all the information that is available to them. For example, Lusardi and Mitchell (2007, 2008) find in survey data that current retirees have very low financial literacy in the sense that they are not able to correctly answer simple questions about interest calculations or riskiness of investments. Moreover, they show that this lack of financial literacy is correlated with the failure to make a financial plan for retirement.

The second kind of limitations are behavioral ones. An example for this kind of limitation can be that people have problems of self control. In that case they find it hard to save because the temptation to consume all their available funds

[1] For an introduction to the field of Household Finance see Campbell (2006).

right away is hard to resist. In other words, their behavior exhibits a present bias. This type of bias has been found in psychological experiments of intertemporal choice - people show signs of time inconsistencies and preference reversals (*inter alia*, Thaler, 1981; Green et al., 1994; Kirby and Herrnstein, 1995; Casari, 2009). For example, suppose given the choice between receiving a small reward tomorrow or waiting for a larger reward one day later, a person chooses to wait for the larger reward. If, however, both payout dates are moved such that the time between the payouts remains unchanged but the smaller reward can be received immediately, a present biased person will tend to reverse his preferences and choose to get the immediate reward, even though the objective gains from waiting did not change.[2] This present bias cannot be explained with the preferences and time discounting commonly employed in economic models. However, in recent years alternative preference specifications have been developed which can account for such a behavior. Most notably, these are Hyperbolic Discounting (Laibson, 1998) and Dynamic Self Control Preferences (Gul and Pesendorfer, 2001, 2004).[3]

These preferences have been applied to different areas of household decisions. Selected examples include the choice of gym contracts (DellaVigna and Malmendier, 2006), drug addiction (Gul and Pesendorfer, 2007), credit card debt (Laibson et al., 2007; Meier and Sprenger, 2010; Kuchler, 2013) and work effort (Kaur et al., 2013). In all these analyses, the predicted behavior of present biased agents significantly differs from the behavior of standard economic agents. Including present bias in these models helps to reconcile the models' predictions with observed data. DellaVigna (2009) gives a broad overview over field experiments concerning behavioral aspects in household decisions.

In my dissertation I address both kinds of limitations. The analyses in the first chapter deal with the effects of informational limitations. In particular, this

[2] For an overview of time discounting and time preferences see Frederick et al. (2002).

[3] A detailed survey on decision theoretic models which accomodate present biased behavior can be found in Lipman and Pesendorfer (2011).

chapter assumes that households are not able to solve the full dynamic programming problem that life-cycle saving requires. Instead, people are assumed to use rules of thumb to make their consumption and savings decisions. The analyses then carefully compare both the behavior and consumer welfare under these rules of thumb with the optimal solution to the life-cycle problem.

The three rules of thumb that are considered are the following: The first rule simply imposes that households always consume exactly their income. This is the simplest rule and goes back to Keynes (1936) and has been used in several for example by Hall (1978), Flavin (1981), and Campbell and Mankiw (1990) in the context of life-cycle consumption-saving decisions. The second rule of thumb is a permanent income rule which is goes back to Friedman (1957). According to this rule people always consume as much as would be sustainable for the rest of their life based on their permanent income. Lastly, the third rule of thumb has been proposed by Deaton (1992a). This rule says that people always try to consume their expected income. If their actual income exceeds what they previously expected they save a fraction of it. If, on the other hand, their actual income falls short of their expectations then they use savings to make up for the difference.

The results in this chapter show that while people might be considerably better off if they made optimal decisions instead of following rules of thumb, the size of their utility loss depends on their income profile, on how uncertain their income is and on their preferences. Utility losses are measured in the percentage increase in consumption in each period that would compensate a person for using a rule of thumb rather than making optimal decisions. When there is no uncertainty about income, utility losses are very low, mostly less than 1% compared to the utility the consumers could optimally attain. Even when income is uncertain, utility losses are below 10% for most scenarios that are considered. People only suffer considerably from using rules of thumb if their preferences are such that they are very risk averse, i.e. if they strongly dislike even small changes in their consumption level.

Moreover, there is no rule of thumb which performs best in all scenarios. Rather, which rule performs best depends on how well each captures the savings behaviour that is required for a specific income process. The three rules differ in the savings motives which they reflect. The Keynes rule does not incorporate any saving, while the Permanent Income rule tries to smooth consumption over the whole life. In contrast, the Deaton rule focuses on smoothing short term income shocks. Hence, if current shocks to income affect income only for a short period of time, the Deaton rule performs best. If, however, shocks to income alter the income path over a long period of time, then the Permanent Income rule performs better since it is aimed at smoothing these long-run shocks.

The second chapter of my dissertation is dedicated to behavioral limitations. In particular, I analyze how problems of self control affect the housing and mortgage decision. While self control has been shown to play an important role in several other areas of household decisions, the effects on this big financial decision has not been analyzed yet. In this chapter I show that self control is also important when people make housing and mortgage decisions. People with problems of self control are less likely to buy a house, they buy smaller houses, and they choose higher loan-to-value ratios. Moreover, I analyze the welfare consequences of financial regulation in the mortgage market. The results of these policy experiments show that whether people benefit or are harmed by regulation policies depends on their degree of self control. In particular, I show that people with problems of self control do not always benefit from financial innovation and can be better off with regulation.

My analysis in this chapter consists of two parts. In the empirical part, I look at survey data of the Panel Study of Income Dynamics and the Health and Retirement Study. In the Panel Study of Income Dynamics I find that people who smoke and people who are obese have on average lower wealth, smaller house values and higher loan-to-value ratios, controlling for standard demographics, income and health. Furthermore, using data from the Health and Retirement Study I show that people who smoke and people who are obese have on average stronger problems of self control.

In the second part of the chapter, I therefore build a life-cycle model of housing and mortgages where I explicitly model the problem of self control. I model agents to have Dynamic Self Control Preferences (Gul and Pesendorfer, 2001, 2004) in the sense that they are always tempted to immediately spend all their available money. Resisting this temptation requires costly self control. I calibrate this model to US data, allowing for the kind of heterogeneity in the degree of self control that I found in the survey data. In the quantified model households with problems of self control choose houses which are up to 6% smaller and loan-to-value ratios of up to 15% higher. These results are in line with the relationships between signs of poor self control and investment behavior found in the survey data.

These effects of self control are the result of two opposing effects. On the one hand, if people have problems of self control then giving up current consumption is hard because they would have to exercise self control. This is the *impatience effect*. It makes current consumption more important relative to future consumption. Houses are therefore less valuable both as a durable consumption good and as investment for retirement. On the other hand, people with costs of self control also take into account that their current actions affect the temptation that they will face in the future and hence their future costs of self control. This *anticipation effect* thus generates a desire for commitment. Houses can be such a commitment device since home equity is an illiquid form of investment which cannot be immediately accessed. By saving in form of home equity instead liquid assets people can therefore save without constantly having to exercise self control.

In the calibrated model I show that both effects are important for the housing and mortgage decision. Overall, however, the quantitative results reveal that the impatience effect dominates the anticipation effect.

I consider two policies of financial regulation. The first policy experiment reveals that a higher minimum down payment requirement can be beneficial for people with costs of self control. Even if this policy makes it harder for them to purchase a house, they can be better off since it also reduces their temptation to buy big houses fully financed with a mortgage. In the second policy experiment I show that the option to refinance a mortgage can reduce welfare for people with high costs of self control. The reason is that refinancing makes it easy to extract home equity from the house. People with costs of self control can therefore no longer use houses as a commitment device for saving which reduces their welfare. The results from these policy experiments therefore reveal that regulation that is optimal for people without costs of self control can harm people who suffer from problems of self control.

II Rules of Thumb in Life-cycle Saving Decisions[4]

Much recent research on households' saving and investment behaviour has focused on financial literacy, that is, on individuals' knowledge of such fundamental financial concepts as compound interest, and their ability to apply such knowledge when making financial decisions; see Lusardi and Mitchell (2007) and van Rooij et al. (2011), *inter alia*. In this paper, we take a different but related perspective on households' savings decisions. We start from the – at least to us – natural assumption that even financially sophisticated individuals do not solve intertemporal optimization models when they make their saving and investment decisions. Rather, they often use simple or sophisticated decision rules, which we call rules of thumb in this paper. The question we ask is: How large is the utility loss that households incur when they use such rules of thumb rather than solve an intertemporal optimization problem?

It is a well-known finding from psychological research on decision-making that individuals use heuristics, or rules of thumb, in making judgements and decisions. In economics, rule-of-thumb behaviour has been recognised as an important aspect of bounded rationality since the seminal work by Simon (1955).[5] Life-cycle consumption and saving decisions are a case in point. There is a large literature on such models and their solution. In realistic versions which incorporate income uncertainty, the solution of the underlying intertemporal optimization problem is rather complicated. It requires backward induction, and no closed-form solution for current consumption as a function of the relevant state variables exists. Many authors argue that individuals are unable to perform the calculations which are

[4]This chapter has been published as Winter, J., Schlafmann, K., and Rodepeter, R. (2012), Rules of Thumb in Life-Cycle Saving Decision, *Economic Journal*, 122:479-501.

[5]For surveys of this literature, see Camerer (1995), Conlisk (1996) and Rabin (1998). Gigerenzer and Todd (1999) provide a psychological perspective on bounded rationality and heuristics.

required to solve the underlying intertemporal optimization problem by backwards induction; see, *inter alia*, Wärneryd (1989), Pemberton (1993), Thaler (1994), and Hey (2005).

Standard economic theory is based on the notion that if individuals have preferences over all possible states of nature at the current and any future date, and if their behaviour is time consistent, there exists some intertemporal utility function that individuals maximise. The standard approach in the literature on households' life-cycle behaviour is to assume that preferences are additively separable over time and that there is some discounting of future utility. More specifically, it is standard to assume that the rate at which individuals discount future utility is constant and that the within-period utility is of the constant relative risk aversion (CRRA) type.[6] There exists a well-defined intertemporal optimization problem that corresponds to these intertemporal preferences. This problem is well understood, and the standard model of life-cycle saving serves as a powerful tool in applied research and policy analysis.[7]

Many important questions remain open, however. Do individuals behave according to the solution of an intertemporal optimization problem? If not, how do individuals make intertemporal choices? Further, if the assumptions of the standard life-cycle model are not empirically warranted, can it nevertheless deliver predictions that are valid in practical applications? There is a large and still growing empirical literature that addresses these issues from different perspectives.[8] It is our reading of this literature that the question whether rational behaviour is an empirically valid assumption in life-cycle models is still open.

[6] There are many papers which depart from this standard model. An important example is the literature on hyperbolic discounting which departs from additive separability and exponential discounting; see Laibson (1998).

[7] Browning and Lusardi (1996), Browning and Crossley (2001), and Attanasio and Weber (2010) review this vast literature. Low et al. (2010) present a recent, sophisticated version of this approach that encompasses wage and employment risk. Blundell et al. (2008) study empirically whether households insure against income shocks; they document partial insurance for permanent shocks and almost complete insurance of transitory shocks among U.S. households.

[8] For reviews of the literature on choice over time, see Loewenstein (1992), Camerer (1995), Rabin (1998), and Hey (2005).

A few examples serve to illustrate this point. In experimental studies of intertemporal decision making, rational behaviour is frequently rejected. In the context of life-cycle models, a series of experimental studies test whether individuals perform backward induction in cognitive tasks that involve some dynamic trade-off, see Johnson et al. (2001), Hey and Dardanoni (1988), and Carbone and Hey (1999). In their experiments, backward induction, and hence rational behaviour, is strongly rejected. In experimental studies of search models (which is an intertemporal decision task slightly different from life-cycle decision making, but more akin to experimental study), Moon and Martin (1990) and Houser and Winter (2004) find that individuals use heuristics that are quite close to optimal, but still different from optimal search rules (which have to be computed by backward induction). Additional evidence on the prevalent use of heuristics in intertemporal or dynamic decision problems comes from a series of experiments by Hey and Lotito (2009), Hey and Panaccione (2011), and Hey and Knoll (2010). More closely related to the topic of this paper, Anderhub et al. (2000) and Müller (2001) document that individuals use relatively sophisticated heuristics, but do not use backwards induction, in experimental studies of a simple saving task. Finally, Binswanger and Carman (2011) present survey data on the use of rules of thumb in actual household decisions. They show that three types of households – planners, rule-of-thumb users, and "unsystematic" savers – each make up about a third of their sample. Interestingly, the wealth outcomes of rule-of-thumb users are similar to those of planners.

In our analysis, we take a normative perspective, maintaining the assumption that individuals have standard intertemporal preferences. Our point of departure is the observation that individuals have limited computational capabilities. We characterise individuals who follow simple heuristics, or rules of thumb, rather than use the decision rule given by the solution to the dynamic optimization model that corresponds to maximizing their preferences. More specifically, we compute life-cycle saving decisions under three different exogenously specified saving rules and compare the outcomes with the optimal solution. The criterion used for this comparison is a consumption equivalent: We express losses in life-time utility associated with rule-of-thumb behaviour in terms of additional consumption required to give individuals the same utility they would achieve if they behaved optimally. The life-cycle model we use is characterised by both income and life-time uncertainty. Both the model and the approach used to solve the dynamic optimization problem numerically are standard in the literature, following Deaton (1991) and Carroll (1992, 1997). Our approach is related to earlier work on near-rational behaviour in intertemporal consumption and saving problems by Cochrane (1989) and Lettau and Uhlig (1999).

Rules of thumb have been analysed in life-cycle saving models before, in particular in tests of the life-cycle/permanent income hypothesis in the macroeconomics literature. Starting with the seminal paper by Hall (1978), a series of studies assume that a fraction of the population behaves according to some simple rule of thumb such as "just consume your current income in every period" while the rest of the population behaves optimally.[9] Estimates of the fraction of rule-of-thumb consumers in the population range between zero and well above 50 percent and depend heavily on assumptions about households' preferences and econometric estimation approaches. In this paper, we explore such a simple consumption-equals-income rule and two other saving rules that have been used in the economics literature on life-cycle saving behaviour. More recently, Scholz et al. (2006) studied saving behaviour using data from a sample of older American households. They show that observed saving decisions are closer to the solution of an intertemporal optimization model than they are to two simple rules of thumb (one assumes a constant saving rate while the second is based on age and income specific average saving rates). Also related to our research question is

[9]The macroeconomics literature on rules of thumb includes papers by Flavin (1981), Hall and Mishkin (1982), Cochrane (1989), Campbell and Mankiw (1990), and Weber (2000, 2002).

a recent study by Calvet et al. (2007) who quantify the welfare losses that result from sub-optimal portfolio choices (which are perhaps driven by rules of thumb as well) using Swedish data.

We should point out that we use the term rule of thumb for *any* decision rule that is (i) not the solution to an underlying utility maximization problem and (ii) easy to derive and apply for individuals with limited computational capabilities. This terminology is consistent with the use in behavioural economics and psychology, as discussed by Goodie et al. (1999). In most of the economics literature, the term "rule of thumb" is typically used in a much more narrow sense, namely, for households that spend a fixed fraction or all of their income in every period; see Deaton (1992b) and Browning and Crossley (2001).[10] This is only one of the rules of thumb we consider. As will become clear below, the other rules of thumb that we analyse are forward-looking and therefore much closer to the life-cycle framework than the "fixed consumption" rule of thumb usually postulated in economics.

The remainder of this paper is structured as follows. In Section II.1, we present a version of the standard life-cycle model of saving decisions which allows for both life-time and income uncertainty. Next, we describe three saving rules which can be used in this framework (Section II.2). In Section II.3, we simulate and compare saving decisions based on the these saving rules. Section II.4 concludes.

II.1 The benchmark life-cycle saving model

We assume that an individual's or household's optimal life-cycle consumption and saving behaviour can be derived from a well-defined intertemporal optimization problem, given additively separable preferences with constant exponential discounting. We use a version of the standard life-cycle model with borrowing constraints and both life-time and income uncertainty which is an extension of

[10] An exception is Deaton (1992a) who specifies a more complicated rule of thumb; see the discussion of Rule 3 in Section II.2 below.

the model proposed by Carroll (1992, 1997). In the remainder, it is understood that the decision-making unit is the household even though we usually refer to individual decisions.

Households are assumed to maximise, at each discrete point τ in time, the expected discounted stream of utility from future consumption. The per-period utility function is denoted by $u(C_\tau)$, to be specified below. Future utility is discounted by a factor $(1+\rho)^{-1}$, where ρ is the time preference rate. The interest rate is denoted by r. The maximum age a person can reach is T, and we define s_t^τ as the probability of being alive in period t conditional on being alive in period τ. To simplify notation, we also use a binary random variable that indicates whether an individual is alive in period t:

$$S_t = \begin{cases} 1 & \text{if the individual is alive in period } t \\ 0 & \text{if the individual is not alive in period } t \end{cases}$$

The individual's intertemporal optimization problem can be stated as follows. In the planning period τ, the maximization problem is given by:

$$\max \{C_t\}_{t=\tau}^{T} E_\tau \sum_{t=\tau}^{T} (1+\rho)^{\tau-t} s_t^\tau u(C_t) \quad \text{s.t.} \tag{1}$$

$$A_{t+1} = (1+r)(A_t + Y_t - C_t) \tag{2}$$

$$A_t \geq 0 \qquad \forall t = \tau \ldots T \tag{3}$$

Maximization of expected discounted utility given by (1) is subject to a standard law of motion for assets A_t (2) and a borrowing constraint (3). Note that while the household will optimally hold zero assets at the end of terminal period T, the individual might die before T with non-zero assets, i. e., there are accidental bequests in our model.

Income Y_t is determined by an exogenous process which is widely employed in the life-cycle literature (see, e. g., Carroll, 1992, 1997; Cocco *et al.* , 2005). This process features a deterministic hump-shaped pattern as well as both permanent and transitory shocks. In particular, income Y_t can be written as

$$Y_t = S_t P_t V_t \tag{4}$$

where P_t is the permanent income component and V_t is the transitory shock. Recall that the random variable S_t reflects life-time uncertainty and takes the value 1 as long as the individual is alive while it is set to zero thereafter. The permanent income component P_t itself follows a random walk with a drift

$$P_t = G_t P_{t-1} N_t \tag{5}$$

where G_t incorporates the deterministic and exogenously fixed hump-shaped life-cycle pattern of income and N_t is the permanent shock. Both transitory shocks V_t and permanent shocks N_t are i.i.d. log-normally distributed random variables with unit expectation and variance σ_v^2 and σ_n^2, respectively.

Finally, we assume that the within-period utility function is of the Constant Relative Risk Aversion (CRRA) type,

$$u(C_t) = \frac{C_t^{1-\gamma}}{1-\gamma}, \tag{6}$$

where γ is the coefficient of relative risk aversion (and the inverse of the intertemporal elasticity of substitution).

As in any model of intertemporal decision making, the individual's decisions can be described by a time-invariant decision rule, i. e., a mapping from states into actions. In the life-cycle saving model, such a decision rule will be a function $C_t = C_t(A_t, Y_t)$ that maps current assets and current income into saving decisions. As noted before, we take the decision rule given by the dynamic programming solution to the intertemporal optimization problem as a benchmark. All other decision rules (i. e., any function that maps states into actions) are interpreted as rules of thumb or heuristics. In the next section, we present three such rules.

Before we analyse how rules of thumb perform relative to the benchmark solution, we conclude this section by briefly sketching how the solution to the intertemporal optimization model given by (1) – (5) can be computed. While there does not exist a closed-form solution, the optimal allocation of consumption over time is characterised by the following first-order condition:

$$u'(C_t) = \frac{1+r}{1+\rho} s_{t+1}^{t} E_t \left(u'(C_{t+1}) \right). \tag{7}$$

This is a modified version of the well-known standard Euler equation in which next period's expected marginal utility is weighted with the conditional probability of being alive in period $t+1$. While the intuition of Euler equations such as (7) – balancing marginal utility across periods – is clear, there does not, in general, exist a closed-form solution which would allow individuals to compute their optimal consumption decision in each period. Rather, every consumer has to solve, in each decision period, the entire life-time optimization model by backwards induction. As noted by many authors before, this procedure is computationally demanding, and we can safely assume that individuals do not actually solve this problem when making their consumption and saving decisions; see, e. g., Hey and Dardanoni (1988). Moreover, Pemberton (1993, p. 5) points out that the intuition behind the Euler equation does not help to find simpler behavioural rules that would generate *as if* behaviour.

To solve the intertemporal optimization problem for the case with implicit borrowing constraints numerically, we apply the cash-on-hand approach by Deaton (1991) in the version developed by Carroll (1992). Cash on hand, denoted by X_t, is the individual's current gross wealth (total current resources), given by the sum of current income and current assets,

$$X_{t+1} = (1+r)(X_t - C_t) + Y_{t+1}. \tag{8}$$

Table 1: Alternative decision rules in a life-cycle savings model

Decision rule	Description	Source
Benchmark	Solution to the underlying intertemporal optimization problem	Carroll (1992), Rodepeter and Winter (1998)
Rule 1	Consumption equals current income	related to Keynes (1936)
Rule 2	Consumption equals permanent income	Friedman (1957)
Rule 3	Consumption equals cash on hand up to mean income, plus 30% of excess income	Deaton (1992a)

In order to reduce the number of state variables we follow the approach in Carroll (1992) and standardise all variables by the permanent income component. The solution to the optimization problem is then computed by backwards induction over value functions starting in the last period in life T where households consume all remaining wealth. Taking this into account the optimal behaviour in period $T-1$ can be computed, etc.

From a more technical point of view we employ equally spaced grids for both standardised cash on hand and standardised savings. Piecewise Cubic Hermite Interpolation is used for points not on the grid. Shocks to the income process are approximated by Gauss-Hermite quadrature.

II.2 Three rules of thumb for life-cycle saving decisions

In this section, we present three decision rules that allow individuals to make their life-cycle saving decisions. Such rules of thumb might be used by individuals which are either unwilling or unable to compute optimal decision rules such as those derived in the previous section. In Section II.3, we use these decision rules to simulate intertemporal consumption-saving decisions. All these decision rules have been proposed in previous literature. Table 1 contains an overview.

The first decision rule is the standard "consume your current income" rule by Keynes (1936). The second rule corresponds to Friedman's (1957) "permanent income" decision rule. The third rule is taken from Deaton (1992a). As we explain below, Deaton designed this rule with the explicit goal that it should be easy to compute but still match optimal behaviour closely. All the rules of thumb we consider are relatively easy to compute, although some might seem to be quite involved. Most importantly, however, these rules do not require using backward induction. Each rule provides a closed-form solution for current consumption given expectations about future income (i. e., given survival probabilities and the expected path of future income).

II.2.1 Rule of thumb No. 1 (Keynes)

The first rule of thumb we consider is the simplest rule one can think of – just consume your current income and don't save at all:

$$C_t = Y_t \tag{9}$$

This rule is related to the famous consumption function by Keynes (1936). We should note that a (macroeconomic) Keynesian consumption rule will typically allow for some constant fraction of current income to be saved in each period. Such a rule does not directly translate to the microeconomic life-cycle saving problem since it lacks an element of dissaving (either in rainy days or in retirement).[11] Here, we use the extreme version that rules out any saving as a benchmark case. In the formal analysis of life-cycle consumption and saving decisions, this rule has been used by, *inter alia*, Hall (1978), Flavin (1981), and Campbell and Mankiw (1990). As simple as it is, this decision rule seems to be natural from a psychological perspective, see Wärneryd (1989).

[11] We return to the issue of whether rules of thumb could be modified or combined to account for different savings motives and stochastic shocks in the concluding section.

II.2.2 Rule of thumb No. 2 (Permanent Income)

The second decision rule is the permanent income rule proposed by Friedman (1957). This rule is much more complicated than the Keynesian consumption rule, but still much easier to apply than the optimal decision rule. Friedman hypothesized that consumption is a function of permanent income which is defined as that constant flow which yields the same present value as an individual's expected present value of actual income. In Friedman's original work, individuals use a weighted average of past income to compute permanent income. In our simulations, we impose rational expectations about future income so that we can compute permanent income based on the realizations of calibrated income processes. Specifically, we start with the identity

$$\sum_{i=t}^{T} Y_t^P (1+r)^{t-i} = A_t + H_t, \tag{10}$$

where Y_t^P is permanent income as of period t, A_t are current assets, and H_t is the present value of (non-asset) income given by

$$H_t = Y_t + E\left(\sum_{i=t+1}^{T} Y_i (1+r)^{t-i}\right). \tag{11}$$

Assuming that individuals consume their permanent income in every period, and re-arranging these identities, we obtain the "permanent income" decision rule,

$$C_t = Y_t^P = \frac{r}{1+r}\frac{1}{1-(1+r)^{-(T-t+1)}}(A_t + H_t). \tag{12}$$

Setting the interest rate to zero for the moment, this reduces to

$$C_t = Y_t^P = \frac{1}{T-t}(A_t + H_t). \tag{13}$$

Here, one can see that individuals distribute their (expected) total wealth equally over their remaining life time, smoothing consumption, but not insuring themselves against utility losses from negative income shocks as in the life-cycle model presented in Section II.1. However, individuals update their expectations about future realizations of the income process. If the stochastic component shows persistence or follows a random walk, permanent income reflects all past and current shocks.

Note that in the absence of income uncertainty (or in the case of certainty equivalence), there is no need for precautionary saving, and this rule of thumb corresponds to the solution of the underlying optimization problem (if one further ignores time preference). In the life-cycle model with income uncertainty presented in Section II.1, the permanent income rule deviates from the benchmark solution. However, as Pemberton (1993) argues, this rule is both forward-looking and easy to compute. Therefore, it might be reasonable to assume such a decision rule for individuals which are "farsighted rather than myopic" and whose "concern is for 'the future' rather than with a detailed *plan* for the future" (p. 7, emphasis in the original). Pemberton refers to the underlying concept as "sustainable consumption". Our simulations allow us to evaluate how such forward-looking behaviour performs relative to the benchmark solution.

II.2.3 Rule of thumb No. 3 (Deaton)

Deaton (1992a) considers a static consumption rule which is relatively easy to compute. It is much simpler than the permanent income rule, but it is not forward-looking. As Deaton states, his goal was to approximate the solution of the underlying optimization problem (a life-cycle model similar to ours) with a rule that "should be simple, simple enough to have plausibly evolved from trial and error" (p. 257). Deaton assumes that individuals consume cash on hand, X_t, as long as cash on hand is less than expected income. If the income

Table 2: Savings motives captured by alternative decision rules

	Benchmark	Rule 1	Rule 2	Rule 3
Consumption smoothing	yes	no	yes	no
Precautionary saving	yes	no	no	yes
Life-time uncertainty	yes	no	no	no

realization exceeds expected income, individuals save a constant fraction, ζ, of excess income (and consume the rest right away). Formally, Deaton's decision rule can be written as:

$$C_t = \begin{cases} X_t & \text{if} \quad Y_t \leq E_t(Y_t) \text{ and } X_t \leq E_t(Y_t) \\ E_t(Y_t) & \text{if} \quad Y_t \leq E_t(Y_t) \text{ and } X_t > E_t(Y_t) \\ E_t(Y_t) + \zeta(Y_t - E_t(Y_t)) & \text{if} \quad Y_t > E_t(Y_t) \end{cases}$$

Below, we follow Deaton in setting this fraction to 30%. Deaton explicitly states that he specified this decision rule, including the choice of $\zeta = 30\%$, entirely *ad hoc*. The intriguing feature of this rule is that while being based on just easy-to-compute expected income, it approximates the optimal solution quite well in Deaton's application. We will show below that this is also true in our slightly more involved life-cycle model.

II.2.4 Saving motives reflected by simple rules of thumb

Before we turn to simulating life-cycle saving decisions using these three rules of thumb, it is useful to briefly review the central motives for saving that operate in our benchmark life-cycle model. Table 2 contains an overview of how these saving motives are reflected in the three simple decision rules that we consider. It is important to recognise that decision rules differ in the motives for saving they reflect. As we will see in the next section, in some specifications of the individual's stochastic environment, not all saving motives are relevant. This implies that there is no universal ranking of these decision rules in terms of their usefulness to individuals.

In a world with uncertainty about the length of life and stochastic income, the intertemporal optimization problem of Section II.1 is designed to capture both risk aversion (i. e., consumption smoothing over time) and precautionary motives (i. e., self-insurance against negative income shocks). Among our three rules of thumb, Deaton's rule is the only one which allows for a precautionary saving motive, while the "consumption equals income" rule includes no saving motive at all. The permanent income rule is forward-looking in the sense that individuals use their expectations about future income, and in the case of persistent shocks also information about past and current shocks, in their consumption and saving decisions. Therefore, this rule reflects the consumption smoothing motive of saving.

II.3 Simulation and evaluation of rule-of-thumb behaviour

In this section, we present simulation results and compute the utility losses associated with using three alternative rules of thumb relative to the benchmark solution, taking preferences as given. More specifically, in order to compare utility losses across different decision rules, we compute a consumption equivalent measure, i. e., the percentage increase in consumption needed in every period and every state which would provide an individual with the same expected life-time utility under a given behavioural rule as she would obtain had she solved the underlying optimization problem. In a different context, this measure of welfare loss has been used by Krueger and Ludwig (2007).

II.3.1 Calibration of the life-cycle model and welfare measure

In Table 3, we report the benchmark parameter values used to calibrate the model. We chose these values to be in the range of values typically used in the literature.[12] The parameter values in the income process have been taken from Cocco

[12] The parameter values used in this study also lie in the range of parameter values obtained using structural estimation by Gourinchas and Parker (2002a) and Cagetti (2003).

Table 3: Parameter values used for calibration of the life-cycle model

Parameter		Benchmark value		
Preference parameters:				
Relative risk aversion coefficient	γ	3		
Rate of time preference	ρ	4%		
Interest rate	r	2%		
Life-time parameters:				
Conditional survival probabilities	s_t^τ	life-table values		
Retirement age		65		
Max. age at death[a]	T	100		
Income process (i.i.d.):				
Variance of transitory shock	$\sigma^2_{e,IID}$	0.25		
Variance of permanent shock	$\sigma^2_{u,IID}$	0		
Income process (random walk):		*no high school*	*high school*	*college*
Variance of transitory shock[b]	$\sigma^2_{e,RW}$	0.1056 (0.0080)	0.0738 (0.0034)	0.0584 (0.0045)
Variance of permanent shock[b]	$\sigma^2_{u,RW}$	0.0105 (0.0011)	0.0106 (0.0004)	0.0169 (0.0006)

[a] In specifications without life-time uncertainty, the age of death is fixed at 80.
[b] Parameters values are from Cocco et al. (2005a).
Standard errors in parentheses.

et al. (2005a). The authors report estimates of the deterministic, hump-shaped life-cycle profile as well as the estimated variance of permanent and transitory shocks. Furthermore, they differentiate between three education groups: households whose head does not have a high school degree, whose head has a high school degree, or whose head has a college degree, respectively. We stratify our simulations by these three education groups. This approach allows us to analyse how the performance of a rule of thumb is affected by the characteristics of the income process faced by the household. Moreover, stratification by education addresses some of the heterogeneity in saving and income insurance that has been documented by Blundell et al. (2008), *inter alia*.

In order to quantify the welfare loss associated with using rules of thumb instead of the optimal solution to the maximization problem we compute a consumption equivalent measure. To be precise we compute the percentage increase in consumption a household following a given rule of thumb would need in each period and in each state in order to have the same expected life-time utility as if she was using the optimal solution. Since the within-period utility function is of the CRRA form there exists a closed form solution for this measure once the expected life-time utility has been computed under both the rule of thumb and the rational behaviour.

The analytic solution for the consumption equivalent can be derived in the following way. Under CRRA preferences the expected life-time utility of a household following a given rule of thumb EU^{ROT} is given by

$$EU^{ROT} = E\left[\sum_{t=0}^{T}(1+\rho)^{-t}s_t^0\frac{(C_t^{ROT})^{1-\gamma}}{1-\gamma}\right] \tag{14}$$

where s_t^0 is the ex ante probability of being alive in period t. The consumption equivalent CE is then defined as

$$E\left[\sum_{t=0}^{T}(1+\rho)^{-t}s_t^0\frac{(C_t^{ROT}\cdot(1+CE))^{1-\gamma}}{1-\gamma}\right]=EU^{OPT} \tag{15}$$

$$\Leftrightarrow \qquad EU^{ROT}\cdot(1+CE)^{1-\gamma}=EU^{OPT} \tag{16}$$

where EU^{OPT} is the expected life-time utility of a household who has solved the maximization problem. Rearranging equation (16) yields the closed form solution for the consumption equivalent measure:

$$CE=\left(\frac{EU^{OPT}}{EU^{ROT}}\right)^{1/(1-\gamma)}-1 \tag{17}$$

In order to obtain the consumption equivalent we thus simulate the discounted life-time utility of 100,000 households both under the optimal solution and under the given rule of thumb. The expected life-time utility under each rule is then computed as the average simulated discounted life-time utility. Equation (17) then directly gives the consumption equivalent measure.[13]

II.3.2 Simulation results

In the following, we first show, for each of the three education groups, the age profiles of consumption spending and asset holdings that arise for the alternative decision rules and in three different scenarios: (i) income certain, life length certain; (ii) income stochastic with i.i.d. shocks, life length uncertain; and (iii) income stochastic as a random walk, life length uncertain. We then summarize the implied utility losses that arise, expressed as consumption equivalents.

Figure 1 shows consumption spending (left column) and asset holdings (right column) for the three educational groups (from top to bottom: no high school,

[13] As an alternative welfare measure we also computed the percentage change in *income* which would give households the same expected utility under a given rule of thumb as under the optimal behaviour. In this case, however, there is no closed form solution since households adjust their behaviour as income changes. The computation is therefore more involved. But under the rules of thumb considered here, households spend most (or even all) of their income anyway, in particular in earlier periods of life. The two welfare measures (percentage increase in consumption and in income, respectively) thus turn out to be almost identical.

high school, college) when there is no uncertainty – the income path is deterministic, and the length of life is known. In this case, realized income is equal to expected income in every period, and so Deaton's Rule 3 collapses to Rule 1, the Keynesian rule. Both rules imply that households consume their deterministic income in every period. Thus, the dashed line that depicts consumption of these households in the graphs in the left column also shows the deterministic income path.

In the absence of impatience (i. e., interest rate r equal to discount rate ρ), behaviour according to Rule 2 (Permanent Income) would be identical to the optimal behaviour of the rational consumer. However, in the benchmark parameterisation, households are impatient, so optimal behaviour (solid line) shifts more consumption to earlier periods in life than permanent income rule (dash-dotted line) would suggest. Note also that since households are borrowing constrained, Rule 2 households consume less than their permanent income early in life. Finally, due to impatience, rational households would like to have a decreasing consumption profile over their life cycle; however due to the borrowing constraint, these households cannot consume more than their income early in life.

The differences between education groups are also interesting. With increasing education, the income profile becomes steeper. The implications are straightforward. Marginal utility of consumption is high for low levels of consumption at the beginning of life and lower for higher consumption levels later in life. For given education and income profiles, consumption levels are identical for all rules as long as households are still borrowing constrained. Between households that follow different rules, differences in consumption arise only later in life, and these differences are more pronounced the higher education and the steeper the income profile.

The right column of graphs in Figure 1 shows asset holdings for the three education groups and alternative decision rules. As noted above, Rule 1 and

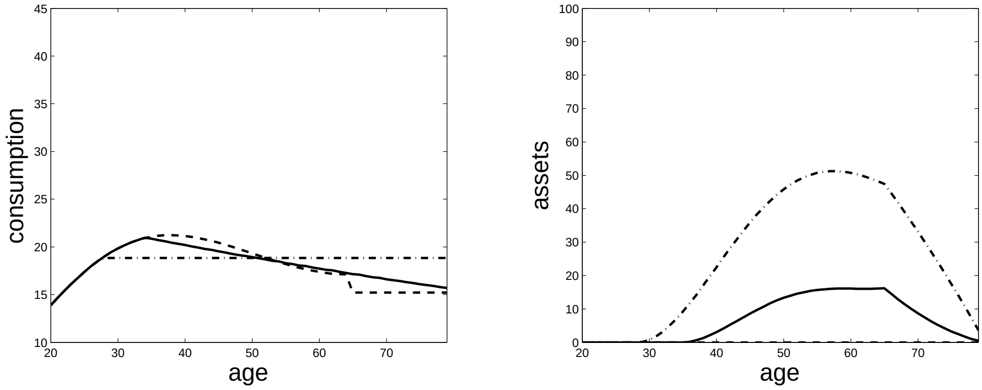
3 (Keynesian and Deaton) households consume their current income in every period so they do not build up any assets. Asset holdings are larger for Rule 2 (permanent income) households than for rational households since the latter prefer earlier consumption because of their impatience.

In Figure 2, we introduce uncertainty: Income follows a stochastic process with a deterministic component and i.i.d. shocks, and the length of life is uncertain. In this environment, rules of thumb can now show whether they succeed in helping households insure against income shocks and life-time uncertainty in the absence of insurance markets. As noted above, we simulated realizations of the stochastic income process for 100,000 households; the graphs in Figure 2 show averages across these simulations, again by education group and decision rule. The graphs in the left column again show consumption spending, those in the right column show asset holdings.

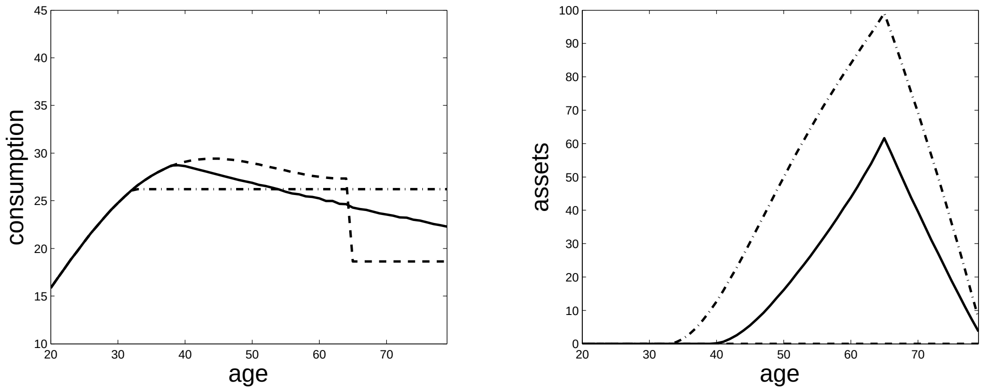
Note first that differences in consumption, and thus also in asset holdings, arise already early in life when households are borrowing constrained, in contrast to the deterministic income case in Figure 1. This is because some households realize positive shocks which are, depending on the decision rule used, not consumed fully. Also for this reason, consumption decisions implied by Rule 1 (Keynesian) and Rule 3 (Deaton) are now different. Another difference to the earlier results is that because of uncertain lifetime, households effectively become more impatient, and impatience increases with age. Thus, consumption is shifted towards younger ages. In particular, rational consumers save less, so their behaviour moves closer to that of Rule 1 and 3 households; conversely, it differs more from that of Rule 2 (permanent income) households. The asset holdings reflect these effects of uncertainty.

A peculiar feature of Rule 3 is that it does not allow for asset decumulation once households are retired. This drawback of this rule is due to its simplicity. One could also imagine that households who follow this rule switch to a different

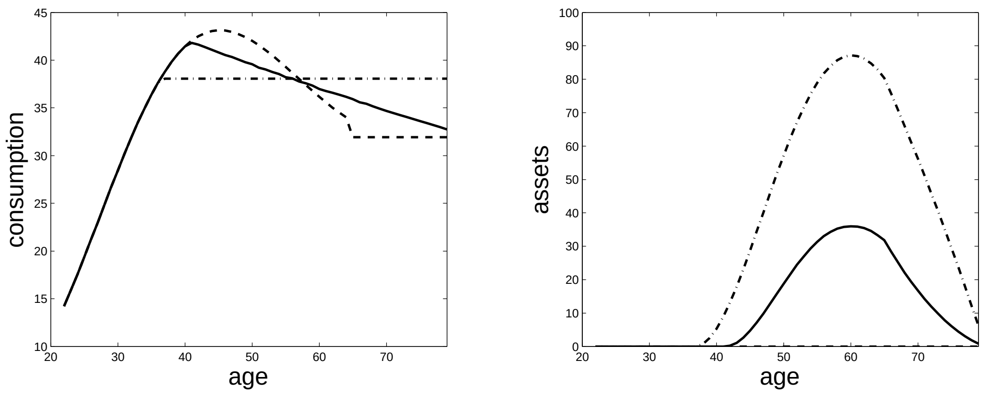
Figure 1: Behaviour due to different decision rules: income certain, life length certain



Panel A: no high school



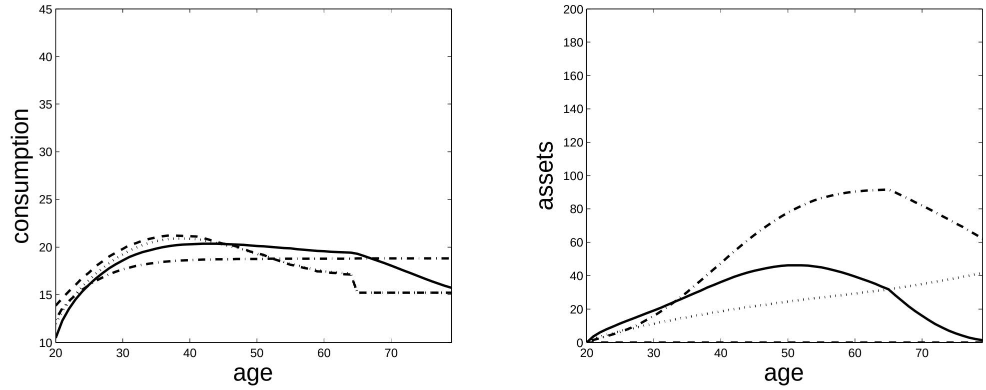
Panel B: high school



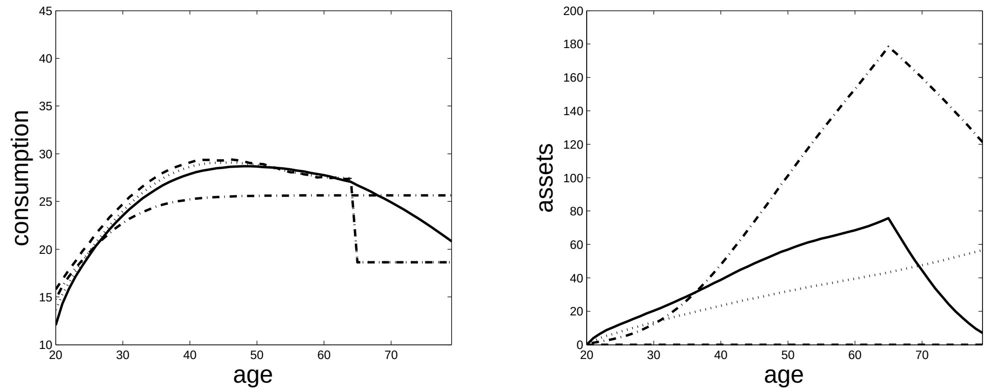
Panel C: college

The figure plots the behaviour generated by the different decision rules: rational behaviour (solid line), Keynes Rule 1 & Deaton Rule 3 (dashed line), Permanent Income Rule 2 (dash-dotted line)

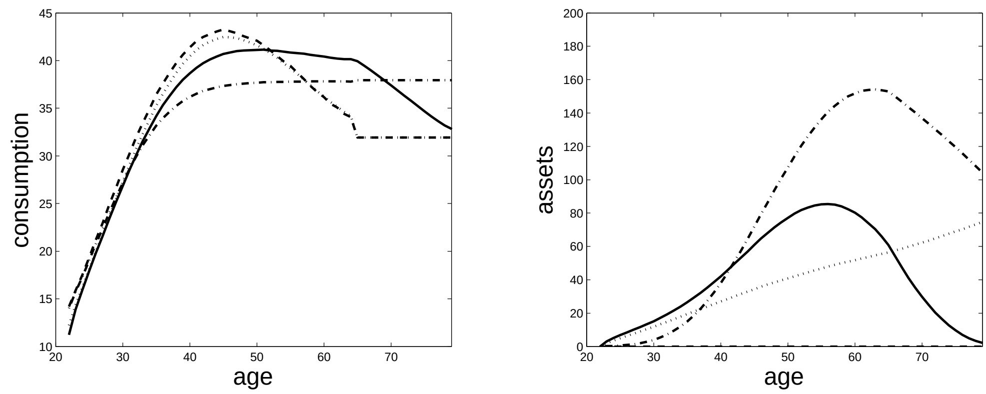
Figure 2: Mean behaviour due to different decision rules: income i.i.d. life length uncertain



Panel A: no high school



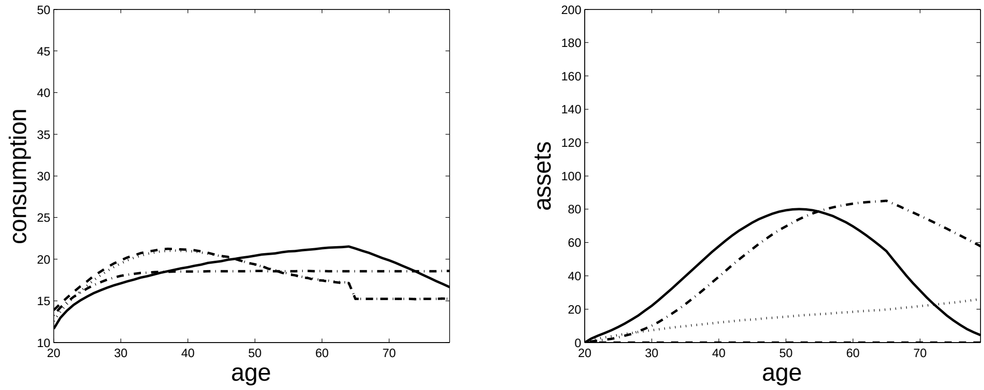
Panel B: high school



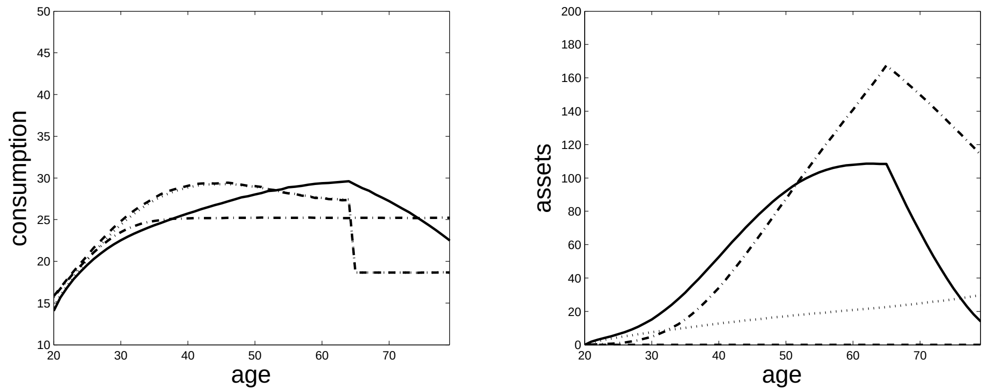
Panel C: college

The figure plots the mean behaviour generated by the different decision rules (calculated from 100,000 simulations): rational behaviour (solid line), Keynes Rule 1 (dashed line), Permanent Income Rule 2 (dash-dotted line), Deaton Rule 3 (dotted line)

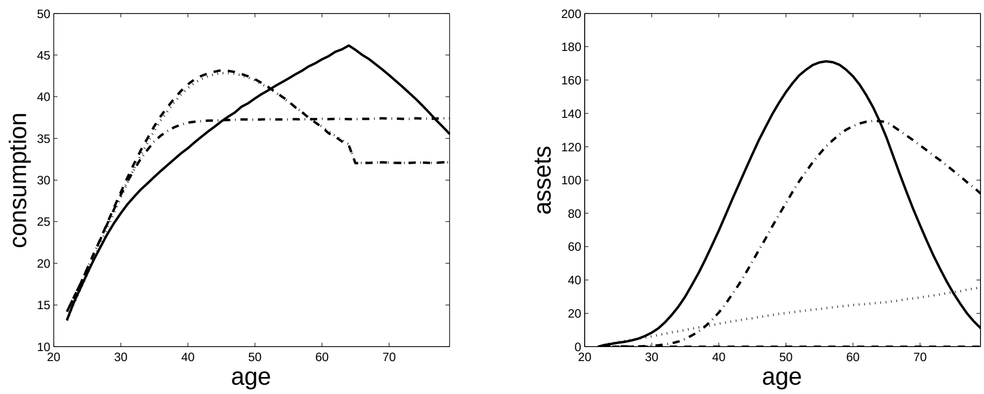
Figure 3: Mean behaviour due to different decision rules: income random walk, life length uncertain



Panel A: no high school



Panel B: high school



Panel C: college

The figure plots the mean behaviour generated by the different decision rules (calculated from 100,000 simulations): rational behaviour (solid line), Keynes Rule 1 (dashed line), Permanent Income Rule 2 (dash-dotted line), Deaton Rule 3 (dotted line) one after retirement. However, we refrain from modeling rule switching in this paper.

Finally, Figure 3, which is similarly structured, shows the average age profile of consumption expenditure and asset holdings when income follows a random walk so that shocks have much more severe consequences. The main implication is that rational households save more and have larger asset holdings than in the i.i.d. case. For the three rules of thumb, the differences are minor.

We now turn to the central question of this paper: How does rule-of-thumb behaviour translate into utility losses, relative to using the optimal decision rule? Table 4 shows utility losses, expressed as consumption equivalents, for a variety of scenarios. More specifically, the numbers in the table are the percentage increases in consumption in each period that would compensate an individual for using a non-optimal decision rule rather than solving the corresponding intertemporal optimization problem.

In Panel A, we report results using the benchmark calibration described in Table 3. When there is no income risk, consumption equivalents (CEs) and thus utility losses are generally very low (less than one percent). The CE is lowest for college graduates since their income profile is the steepest. This implies that their marginal utility is very high early in life relative to low marginal utility later in life when their consumption level is very high. But differences between the decision rules only occur once households are no longer credit constrained and their consumption level is already high. Hence, college graduates require only a small increase in consumption in the early periods to compensate for the relatively low utility losses later in life. The CEs are relatively high for households in the middle education group that follow Rules 1 and 3: These households face a large drop in income at retirement which is not smoothed by these rules. These results provide a first important insight: Utility losses implied by rules of thumb depend on the income profile, both in early life and around retirement, and they

Table 4: Life-time utility loss from using alternative decision rules

Income	Length	No high school			High school			College		
	of life	Rule 1	Rule 2	Rule 3	Rule 1	Rule 2	Rule 3	Rule 1	Rule 2	Rule 3
Panel A: benchmark calibration										
certain	certain	0.2	0.7	0.2	0.9	0.4	0.9	0.1	0.2	0.1
certain	uncertain	0.0	3.0	0.0	0.4	2.7	0.4	0.0	1.1	0.0
i.i.d.	certain	24.7	4.3	6.9	21.8	6.7	6.2	15.9	8.3	3.7
i.i.d.	uncertain	24.2	5.0	6.4	21.1	7.1	5.6	15.6	8.5	3.5
random	certain	19.9	2.8	11.7	14.2	2.7	9.8	14.4	4.3	11.4
random	uncertain	16.9	3.4	8.8	11.0	3.6	6.5	11.1	4.2	8.2
Panel B: high risk aversion ($\gamma = 9$)										
certain	certain	1.5	0.1	1.5	1.7	0.0	1.7	0.0	0.0	0.0
certain	uncertain	0.9	1.1	0.9	1.2	0.4	1.2	0.0	0.0	0.0
i.i.d.	certain	40.5	32.4	32.0	32.9	30.4	29.2	4.4	4.0	2.0
i.i.d.	uncertain	39.4	32.1	32.0	32.8	30.2	29.2	4.4	4.0	2.0
random	certain	179.2	55.5	141.1	140.3	46.8	135.1	170.8	72.0	162.4
random	uncertain	160.2	44.3	125.5	118.5	39.1	113.0	149.3	59.5	140.8
Panel C: high variance of permanent shocks (+ 3 standard errors)										
random	certain	26.4	4.8	17.9	16.3	3.3	11.7	17.3	5.4	14.2
random	uncertain	22.0	4.8	13.4	12.4	4.0	7.9	13.4	5.0	10.4

Life-time utility losses are expressed as the percentage increase in consumption in each period and state that would compensate an individual for using non-optimal decision rules rather than solving the corresponding intertemporal optimization problem. Parameter values for the benchmark model are reported in Table 3.

are not necessarily ranked by education.

There are also differences in CEs depending on whether the length of life is uncertain. As mentioned above, life time uncertainty effectively makes agents more impatient. Hence rational households shift more consumption to earlier periods in life. This implies that rational behaviour differs more from the consumption profile implied by the permanent income rule, and thus the utility loss of following this rule increases.

Next, consider the case with stochastic income (the third and fourth lines of Panel A). Rule 1 (Keynesian) households do poorly now since not smoothing transitory income shocks is very costly: their CE goes up to between 15 percent (high education) and 25 percent (low education). CEs for the other two rules also increase relative to the certain income case, but they remain below 10 percent for all education groups. Deaton's Rule 3 does quite well – this is exactly the environment for which it was designed. Rule 2 (permanent income) does relatively poorly for high education households whose income profile is steep so that borrowing constraints bind longer. Whether lifetime is uncertain or not does not have a major effect.

The random walk case (the last two lines of Panel A) is perhaps most realistic. Even though income shocks now have permanent effects, CEs are still relatively low (mostly below 10 percent), in particular for Rules 2 and 3. Here, the permanent income rule does well because it takes shocks into account by updating permanent income. However, there is no smoothing of small shocks early in life because of borrowing constraints, so utility losses relative to optimal behaviour still arise. Only the Keynesian Rule 1 does poorly, even though CEs are smaller than in the i.i.d. case.

Before we turn to a more general interpretation of these results, we briefly discuss Panels B and C of Table 4. In these simulations, we use alternative parameter values to investigate the sensitivity of our results with respect to households' risk aversion and the variance of the income process. In Panel B, we increase risk aversion by setting the coefficient γ equal to 9 rather than 3. If risk aversion is higher, the curvature of the utility function is larger, so the effects of steep income profiles are more pronounced. As long as income is certain, high school graduates that follow any of the rules of thumb come close to optimal behaviour in utility terms. For the other education groups, CEs tend to increase when risk aversion increases for most decision rules but they remain low. When income is uncertain, higher risk aversion affects rule-of-thumb households quite negatively unless they have very steep income profiles. For the low and middle education groups, CEs go up considerably in the i.i.d. case. Finally, when income follows a random walk, high risk aversion households fare very poorly under any rule of thumb; Rule 2 (permanent income) does slightly better.

In Panel C we increase the variance of the permanent income shock in the random walk case by 3 standard errors. These numbers should be compared with those in the last two lines of Panel A. It is apparent that increasing income variance makes rules of thumb perform less well; CEs increase across the board. However, they typically remain below 20 percent which is perhaps surprisingly low given that the income process has now a rather large variance. As before, Rule 2 (permanent income) performs best in the random walk case since it updates permanent income after each shock.

We can draw several conclusions from the numbers in Table 4. In the case of income certainty, life-time utility losses resulting from following some rule of thumb rather than solving the underlying intertemporal optimization problem are relatively small. When income is uncertain, individuals who follow rules of thumb in their consumption and saving decisions suffer considerable utility losses relative to the optimal decision rule. Not surprisingly, the magnitudes of these utility losses depend on preferences (here we studied risk aversion) and the specific structure of the income process. There are also many cases in which rules of thumb do not imply substantial utility losses, and rules of thumb which are simpler than others (such as Deaton's rule) do not necessarily perform worse. Unless risk aversion is very high ($\rho = 9$), utility losses as expressed by consumption equivalents are below 20 percent, and the permanent income rule stays even below 10 percent.

The main conclusion from this comparison is that there is considerable variation in the life-time utility loss associated with using rules of thumb. There is no uniformly best rule of thumb, and for most stochastic environments analysed in this paper, there is some rule of thumb which yields relatively small utility losses (less than 10% of life-time income). In the case of uncertain length of life and a random walk income process, however, utility losses are substantial for all rules of thumb. When risk aversion is very high, using a rule of thumb is a particularly bad idea. This observation is interesting since one might speculate that in real life, households with high risk aversion might also be those who are financially less sophisticated and thus more likely to use rules of thumb. Similarly, high education households which might be more likely to use sophisticated savings strategies would actually perform relatively better using rules of thumb than low-education households since their income profiles are steeper.

What does a rule of thumb make perform well? Based on our results, we conclude that the key factor that makes a rule of thumb successful is its ability to generate a measure of life-time income that correctly reflects movements in future income. If the life-time income process exhibits a strong deterministic trend and modest shocks with low persistence, this might not be too difficult. We discuss some implications of this finding in the concluding section.

II.4 Conclusions

In our simulations of life-cycle consumption and saving decisions under three heuristic decision rules, we found that losses in total life-time utility can, in general, be substantial compared with optimal behaviour (i. e., using the solution of the underlying intertemporal optimization problem for given standard life-cycle preferences). The magnitudes of these losses vary with the assumptions about preference parameters and the properties of the income process. An important result is that for most environments we simulated, there exists some simple rule of thumb which results in only modest utility losses (expressed by compensating variations, these losses are equivalent to between 5 % and 10 % of life-time income).

We conclude this paper with a discussion of possible extensions of our analysis and implications for future research in the life-cycle consumption and saving framework. The saving rules we analysed in this paper reflect two distinct motives for saving (consumption smoothing and precautionary saving). A natural extension of our approach would be to combine two or more of these rules of thumb. For example, individuals could use a simple static rule such as Deaton's rule (Rule 3) to insure themselves against adverse income shocks, and at the same time, they could do some consumption smoothing by using forward-looking rules, i. e., the permanent income rule (Rule 2) which focuses on income uncertainty. By combining several rules of thumb, individuals should be able to improve their total life-time utility considerably, and they might actually come quite close to using the solution to the underlying optimization problem in utility terms. The concept of mental accounting introduced to the life-cycle saving literature by Shefrin and Thaler (1988) is closely related to the notion of using multiple rules of thumb. For instance, mental accounting implies that individuals make saving decisions with different time horizons and saving goals in mind. Combining rules of thumb with different objectives such as those analysed in this paper with a mental accounting framework appears to be a fruitful direction for future research.

Unfortunately, combining two or more saving rules in our framework would complicate the analysis considerably, both technically and conceptually. The optimization and simulation problem is obviously much more involved, but more importantly, one would have to make assumptions of how individuals allocate funds to different saving rules. This allocation might change over the life cycle. This would imply that a second class of behavioural decision rules would have to be specified for the allocation of saving into different mental accounts.

It would also be interesting to compare the welfare consequences of suboptimal savings decisions (the subject of the present paper) with those of suboptimal portfolio choices (as in Calvet *et al.* , 2007) when both are driven by rules of thumb. To perform such a comparison, both simulation models would have to be specified and calibrated consistently, or perhaps even embedded in a unified model. Such an analysis would allow us to address the question of whether it is more important to use good rules of thumb for the consumption-saving decision or for the decision of how to invest whatever amount is saved.

Another important research question that we have not addressed in this paper is: How do rules of thumb actually arise? How do individuals decide which behavioural decision rule they use? In our analysis, we have taken the rules of thumb as exogenously given because our main objective was to evaluate the utility loss associated with using some heuristic rather than computing the optimal solution to the underlying decision problem. We did not model the choice between the optimal strategy and using rules of thumb. Rule-of-thumb behaviour could be derived from some meta problem if the cost of computing the solution to the underlying life-cycle optimization problem was taken into account.[14] However, such an approach might run into the conceptual problem of an infinite regress, as discussed by Conlisk (1996).

A promising approach is to explore how rules of thumb arise endogenously from learning behaviour; for example, Lettau and Uhlig (1999) investigate a model of learning rules of thumb in intertemporal decision problems. However, in a life-cycle saving setting, learning from own mistakes is impossible. Every life-cycle

[14]Computation costs have been considered in models with rule-of-thumb behaviour by Shi and Epstein (1993) and Hindy and Zhu (1997).

decision is made only once – all decisions are conditional on the planning period (i. e., on age) and cannot be repeated with a different "trial" decisions in the future. Therefore, learning in the life-cycle saving problem is likely to be based on social interactions with other people (family, neighbors, or friends). Brown et al. (2009) present evidence for the relevance of learning: In an experimental study with artificial life-cycle decisions, subjects saved too little initially but learned to save optimally as life cycles were repeated. In the domain of entrepreneurial financial decisions, Drexler et al. (2010) conducted a field experiment with micro-entrepreneurs in the Dominican Republic and found that simple rule-of-thumb training improved business practices and outcomes. An important question for future research thus seems to be how individuals acquire the rules they use for making financial decisions, and whether policy interventions can help individuals to improve the rules they use. This research agenda is obviously related to the ongoing discussion of how households' financial literacy can be improved.

Certain institutions might also provide individuals with saving rules so that they don't need to figure out optimal or heuristic saving rules themselves. An important example is social security which replaces the need for discretionary long-term saving to some extent. Another mechanism that provides rules for long-term saving is housing expenditure. In countries such as the U.S. and the U.K., many households buy their first family homes relatively early in their life cycle, and this decision determines a large fraction of their consumption and saving pattern over future years. In Germany, due to its favorable tax treatment, the acquisition of life-insurance policies with substantial saving components during the early stage of the active working life has been quite common in the past, see Sauter and Winter (2010). The acquisition of a family home or a life-insurance policy is a one-time decision that fixes a substantial part of life-cycle saving and it reduces the scope for discretionary saving over remaining years substantially. There is also some recent evidence that individuals are quite willing to follow saving rules provided by institutional arrangements; e. g., Thaler and Benartzi (2004) and Choi et al. (2005). The behavioural patterns mentioned in this paragraph (based on direct imitation, social traditions, or institutional arrangements) can be interpreted as following a heuristic saving rule, and they might result in decisions that are quite close to optimal life-cycle behaviour.

Any empirical analysis of rule-of-thumb saving behaviour would have to account for the possibility that individuals are heterogeneous with respect to the decision rules they use. Once we give up the fiction of optimal behaviour based on the solution to a (unique) underlying optimization problem, the result that all individuals follow the same decision rule does not need to hold any more. Some individuals might care more about short-term precautionary saving, some for long-term consumption smoothing, while others might rely on saving rules provided by institutional arrangements. As noted above, combinations of rules might arise as well. To our knowledge, there exist no econometric studies that try to identify individual decisions rules in a life-cycle saving context, but this is clearly an important area for future research that could build on results from laboratory experiments on decision rules in dynamic problems by Müller (2001), Houser and Winter (2004), and more recently Hey and Lotito (2009), Hey and Panaccione (2011), and Hey and Knoll (2010).

Based on our results on the performance of simple saving rules, we would argue that an important direction for research on life-cycle consumption and saving behaviour is how social learning and institutional factors generate simple decision rules, and to test whether individuals actually use such rules with micro data on household consumption and saving.

III Housing, Mortgages, and Self Control

Since the recent crisis in the housing and mortgage market regulators across the globe have been assessing the usefulness and dangers of mortgage products. For example, both in the United States and in the United Kingdom regulators recently issued rules which limit the use of mortgage types which are deemed to harm consumers' welfare (Consumer Financial Protection Bureau, 2013; Financial Services Authority, 2012). However, to assess if certain aspects of mortgage products are harmful to consumers' welfare it is necessary to understand what determines housing and mortgage decisions.

In this paper I show that self control is important for the housing and mortgage choice in two respects. First, self control affects the housing and mortgage decisions. People with higher costs of self control are less likely to own a house, own smaller houses and have higher loan-to-value ratios. Second, their degree of self control determines if households benefit or are harmed by regulation policies which limit the use of certain mortgage products. I consider two policies of financial regulation. The first policy experiment reveals that a higher minimum down payment requirement can be benefial for people with costs of self control. Even if this policy makes it harder for them to purchase a house, they can be better off since it also reduces their temptation to buy big houses fully financed with a mortgage. In the second policy experiment I show that the option to refinance a mortgage can reduce welfare for people with high costs of self control. The reason is that refinancing makes it easy to extract home equity from the house. People with costs of self control can therefore no longer use houses as a commitment device for saving which reduces their welfare.

I start my analysis by documenting the correlations between signs of poor self control and housing and mortgage outcomes using data from the Panel Study of Income Dynamics and from the Health and Retirement Study. In the main part of the paper I then build a quantitative life-cycle model to analyze the mechanism of how self control effects the housing and mortgage decisions. To allow for a very flexible choice set I implement the model using the simplex method. I then calibrate it to the US economy allowing for heterogeneity in the degree of self control.

Using data from the Health and Retirement Study I show that smoking and being obese are signs of poor self control. Furthermore, in data from the Panel Study of Income Dynamics I show that people who smoke and people who are obese have a significantly different savings and investment behavior than non-smokers or people who are not overweight. They have overall lower wealth, own houses with lower value and have higher loan-to-value ratios in their houses. After controlling for income, health and other demographics these effects are big, comparable in size with the effects of only having a high school degree instead of a college degree. These empirical analyses hence suggest that self control plays a role when households make their housing and mortgage decisions.

To understand how self control affects the housing and mortgage choice I build a structural life-cycle model. I model self control by assuming that households have Dynamic Self Control Preferences (Gul and Pesendorfer, 2001, 2004) in the sense that they are always tempted to maximize their current utility instead of their expected life-time utility. I find that in the calibrated model reasonably small costs of self control lead to economically significant effects on the housing and mortgage choice. Households with costs of self control choose houses which are up to 6% smaller and loan-to-value ratios of up to 15% higher. These results are in line with the relationships between signs of poor self control and investment behavior found in the data.

These differences in behavior are the result of two opposing effects. On the one hand, people with costs of self control find it harder to give up current consumption because this would lead to current costs of self control. This is the *impatience effect*. It makes current consumption more important relative to future consumption. Houses are therefore less valuable both as a durable consumption good and as investment for retirement. On the other hand, people with costs of self control also take into account that their current actions affect the temptation that they will face in the future and hence their future costs of self control. This *anticipation effect* thus generates a desire for commitment. Houses can be such a commitment device since home equity is an illiquid form of investment which cannot easily be spend. People with costs of self control are thus not tempted to spend this part of their savings which reduces their costs of self control. In the calibrated model I show that both effects are important for the housing and mortgage decision. Overall, however, the quantitative results reveal that the impatience effect dominates the anticipation effect.

Moreover, I use my model to analyze the welfare consequences of financial regulation in the mortgage market. If people have costs of self control then policies which reduce their choice set not only restrict their actual behavior but also change the temptation that they face each period. I show that welfare benefits from reducing the temptation can overcome the welfare loss of having to alter one's behavior. Agents with costs of self control can hence benefit from policies which would reduce the welfare of people without costs of self control. To assess the consequences of financial regulation it is therefore important to take costs of self control into account.

I look at two specific policy experiments: First, I analyze the effects of an increase in the minimum down payment requirement. In this case households have to pay a higher share of the purchase price up-front in the period in which they buy a house. People who would have financed the purchase solely by taking out a mortgage in the unrestricted model can hence no longer do so under the new policy. For people without costs of self control this is the only effect and they can therefore never be better off with this policy. For people with costs of self control, however, there is a second effect. If the minimum down payment requirement is very low then they are tempted to buy a big house by taking out a big mortgage. Exercising self control to resist this temptation is hard. Increasing the minimum down payment hence reduces the temptation the agents face each time they consider buying a house. In the calibrated model I show that this reduction in temptation outweighs the negative effect of having to adjust their behavior. Agents with costs of self control are hence better off with a substantial minimum down payment requirement. Moreover, I show that this is particularly true for poorer agents who are less likely to actually become home owners but who are constantly tempted to buy a house by taking out a big mortgage.

Second, I show how the option to refinance a mortgage affects the welfare of households. For all households the possibility to refinance their mortgage implies that they can more easily adjust their leverage position and use their home equity to smooth income shocks. For households without costs of self control this is the only effect and they are hence unambiguously better off if refinancing is possible. However, the fact that people can easily access their home equity by refinancing instead of having to wait until the house is sold reduces the commitment value of the house. Without the option to refinance households with costs of self control can save in form of home equity without constantly being tempted to spend these savings. If refinancing is possible, however, they will be tempted to extract home equity by refinancing so that buying a house is no longer a commitment device. I show that in the calibrated model the degree of self control determines which of the two effects dominates. While people without costs of self control unambiguously benefit from the possibility to refinance, people with costs of self control are worse off if the costs are sufficiently large. Furthermore, the welfare loss is higher for wealthier households since they are more likely to be home owners and hence to benefit from the commitment device if it is available.

My paper is related to the literature in two areas. First, it is related to papers on housing and mortgages. This area has been the subject of great interest since the crisis in the housing and mortgage market. Studies which focus on life-cycle considerations include Campbell and Cocco (2011), Chambers et al. (2009), Attanasio et al. (2012).[15] My model extends the housing and mortgage literature by analyzing how self control affects these choices. In a recent paper, Ghent (2013) also considers a model of housing with agents who have self control problems. She compares equilibria of economies in which all agents have standard preferences with those in which agents discount the future quasi-hyperbolically. The current paper has a different goal: It starts from evidence on heterogeneity of preferences in household survey data. I then emphasize the differential welfare effect of restricting choice sets on agents with and without self control problems. In addition, in contrast to the earlier literature, this paper allows for continuous choices of both house size and mortgage balance, a feature that is important for my quantitative results.

The second stream of literature that my paper directly relates to is the analysis of self control in other household decisions. Temptation and self control were found to play a role in various contexts, for example in the choice of gym contracts (DellaVigna and Malmendier, 2006), for credit card debt (Laibson et al., 2007; Meier and Sprenger, 2010; Kuchler, 2013), in the workplace (Kaur et al., 2013) and for drug addiction (Gul and Pesendorfer, 2007).[16] Moreover, Krusell et al. (2009, 2010) and Amador et al. (2006) give a more theoretical treatment of effects of self control.

The remainder of this paper is organized as follows. In section 2 I show that people who show signs of poor self control empirically have a different housing and mortgage portfolio. Section 3 then describes the structural model I use to analyze how self control affects the housing and mortgage choice. In section

[15] There is also an important stream of literature emphasizing the macroeconomic effects of the housing and mortgage market. Studies in this area include, for example, Barlevy and Fisher (2011), Chatterjee and Eyigungor (2011), Chen et al. (2012), Corbae and Quintin (2011) and Iacoviello and Pavan (2011).

[16] DellaVigna (2009) gives an overview over field experiments concerning behavioral aspects in household decisions.

4 I show the results of the calibrated model and analyze how two policies of financial regulation affect the choices and welfare of agents with costs of self control. Section 5 concludes.

III.1 Signs of Self Control in the data

In this section I show that households who exhibit behavioral patterns which are signs of poor self control have systematically different housing and mortgage outcomes. The Health and Retirement Study (HRS) contains a test module in its wave 2010 that asks about a person's self control. This gives an explicit measure of self control in the cross-section. However, housing and mortgage choices are typically made in the first part of working life while the sample in the HRS is representative for the population close to or already in retirement. It is therefore not possible to directly analyze the effects of self control on the housing and mortgage choice in this data set. To address this, I link the degree of self control to observable behavior which is typically associated with lack of self control. These behavioral indicators are in turn present in the Panel Study of Income Dynamics (PSID) where I have data on the housing and mortgage positions of households over the whole life cycle. I use PSID data to show that there is unexplained variation in the housing and mortgage positions that is systematically correlated with signs of poor self control.[17]

III.1.1 Self Control and Behavioral Patterns

The Health and Retirement Study is a panel data set that focuses on individuals who are close to or already in retirement. It consists of an abundance of health measures, personality questions as well as wealth and income information. In particular, wave 2010 contains a module that specifically asks the participants

[17] At no point in this empirical analysis do I claim to identify causal effects. I show that there is significant correlation between signs of poor self control and the outcomes of housing and mortgage decisions. I then build a structural life-cycle model to analyze how self control affects the housing and mortgage choice.

to assess their self control. There are questions about four specific dimensions of self control (financial, food, exercise, and interpersonal) as well as self control in general. Since the housing and mortgage decision is mostly a financial one, I focus on financial and on general self control. Regarding general self control, the interviewee is asked to assess how much the following statements resemble him on a scale from 1 to 5 (1: "Very much like me", 5: "Not like me at all"):

> *I wish I had more self-discipline.*
> *I am good at resisting temptation.*
> *Sometimes I can't stop myself from doing something, even if I know it's wrong.*

To assess financial self control, the interwiewee is asked to answer on a scale from 1 to 5 how often they do certain things (1: "Very often", 5: "Never"):

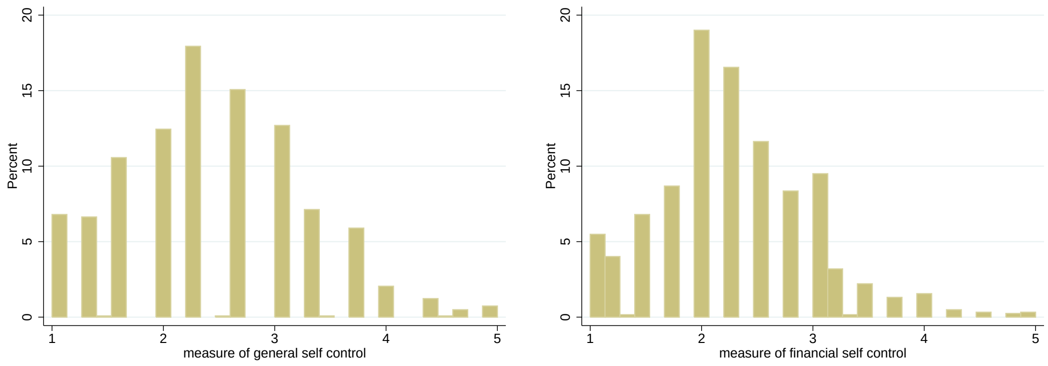
> *Spend too much money?*
> *Buy things on impulse?*
> *Buy things you hadn't planned to buy?*
> *Buy things you don't really need?*

I follow the designer of the module, Angela Duckworth (see Tsukayama et al., 2012), and construct averages of the answers as measures for general self control and financial self control, respectively.[18] Figure 4 shows the distribution of the two measures, where a higher value corresponds to a stronger problem of self control.[19]

To gain further insight into these measures of self control, I relate them to behavioral indicators which are typically associated with a lack of self control: smoking, being overweight, not exercising regularly, and drinking alcohol. Since the sample in the HRS consists of people who are mostly in retirement, only few

[18]Before taking the average, the orientation of the question has to be taken into account.
[19]See appendix A for details about the sample selection.

Figure 4: Distribution of Self Control Measures in HRS



(a) general self control (b) financial self control

Source: Health and Retirement Study (HRS), wave 2010, module 5 "Personality", and own caluculations
Note: Distribution of the two measures of self reported self control in the HRS sample, where a higher value corresponds to a stronger problem of self control.
Definitions: The measures have been constructed as the average response to the following questions (taking question orientation into account):
General Self Control (scale 1 to 5, 1: "Very much like me", 5: "Not like me at all"):
a) I wish I had more self-discipline. b) I am good at resisting temptation. c) Sometimes I can't stop myself from doing something, even if I know it's wrong.
Financial Self Control (scale from 1 to 5, 1: "Very often", 5: "Never"):
How often do you... a) Spend too much money? b) Buy things on impulse? c) Buy things you hadn't planned to buy? d) Buy things you don't really need?

individuals still smoke. For the smoking behavior, I therefore construct a dummy variable which indicates if a person has ever smoked as opposed to smokes at the time of the interview. The characteristic of being overweight is measured according to a person's Body Mass Index (BMI), a commonly employed measure of body shape which relates a person's weight to his height.[20] For the indicator if a person doesn't regularly exercise I again take into account that the survey is representative for the older population. I therefore set the dummy equal to one if the interviewee states that he engages less than once a month in moderate or vigorous physical exercise, where moderate is defined as, for example, gardening, going for a walk, or cleaning the car. Lastly, alcohol consumption is reflected in

[20]The exact formular is BMI = mass(kg) / height(m)^2. According to the U.S. Department of Health & Human Services, a person is classified as underweight for a BMI < 18.5, normal for for a $18.5 \leq$ BMI < 25, overweight for $25 \leq$ BMI < 30, and obese for BMI ≥ 30. I use the same classification.

Table 5: Behavioral Indicators in HRS

	%
Smoking	
never smoked	44.31
has smoked / smokes	55.69
BMI	
normal	31.20
overweight	37.51
obese	31.29
Exercise regularly	
exercises regularly	68.80
doesn't exercise regularly	31.20
Alcohol consumption	
doesn't drink alcohol	49.55
drinks alcohol	50.45
Observations	1221

Source: Health and Retirement Study (HRS), wave 2010, and own caluculations

Note: The table shows the distribution of the behavioral indicators in the HRS sample.

Definitions: The behavioral indicators are defined to take the age of the HRS sample (representative for population over 50) into account: *Smoking* distinguishes between people who have never smoked and people who either still smoke or have smoked earlier in their life. *Body Mass Index (BMI)* is defined as BMI = mass(kg) / height(m)^2, classification into categories according to the U.S. Department of Health & Human Services. *Exercise regularly* is defined as at least once a month moderate or vigorous physical exercise (e.g. gardening, going for a walk, cleaning the car). *Alcohol consumption* distinguishes between people who do not drink any alcohol and those who do.

a dummy indicating if a person drinks any alcohol. Table 5 gives the distribution of the behavioral indicators in the sample.

Table 6 shows that exhibiting these types of behavior is positively correlated with reporting a problem of self control. Note that these correlations remain after controlling for standard demographic differences such as age, marital status, race, education, retirement status, and income. In the next subsection I will thus relate these signs of poor self control to financial variables of interest.

Table 6: Conditional Correlations in HRS

	(1) general self control	(2) financial impulsivity
ever smoked	0.117**	0.095**
	(0.049)	(0.041)
BMI		
overweight	0.102*	0.142***
	(0.057)	(0.049)
obese	0.191***	0.200***
	(0.061)	(0.051)
no exercise	0.095*	0.041
	(0.053)	(0.045)
drinks alcohol	0.081*	0.124***
	(0.049)	(0.042)
Observations	1221	1221
R^2	0.046	0.080

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Health and Retirement Study (HRS), wave 2010, and own caluculations

Note: Conditional correlations of the self control measures with behavioral indicators in the HRS sample, obtained by OLS with additional control variables: age, marital status, race, education, retirement status, and income. A higher measure of self control refers to worse self control.

Definitions: Measures of self control have been constructed as the average response to the following questions (taking question orientation into account):
General Self Control (scale 1 to 5, 1: "Very much like me", 5: "Not like me at all"):
a) I wish I had more self-discipline. b) I am good at resisting temptation. c) Sometimes I can't stop myself from doing something, even if I know it's wrong.
Financial Self Control (scale from 1 to 5, 1: "Very often", 5: "Never"):
How often do you... a) Spend too much money? b) Buy things on impulse? c) Buy things you hadn't planned to buy? d) Buy things you don't really need?
Behavioral indicators are defined to take the age of the HRS sample (representative for population over 50) into account: *Ever smoked* = 1 if person currently smokes or has smoked earlier in life. *Body Mass Index (BMI)* is defined as BMI = mass(kg) / height(m)^2, classification into categories according to the U.S. Department of Health & Human Services. *no exercise* = 1 if person engages less than once a month moderate or vigorous physical exercise (e.g. gardening, going for a walk, cleaning the car). *drinks alcohol* = 1 if person drinks any alcohol.

III.1.2 Behavioral Patterns vs. Housing and Mortgage Outcomes

The behavioral indicators which I have shown to be a sign of poor self control in the HRS are also available in the Panel Study of Income Dynamics (PSID). In particular, since wave 1999 information about smoking, drinking, exercising as well as height and weight have been added to the survey. In order to use as

Table 7: Behavioral Indicators in PSID

	all obs %	home owners %
Smoking		
don't smoke	73.69	76.86
smoke	26.31	23.14
BMI		
normal	20.73	19.31
overweight	46.90	48.17
obese	32.37	32.52
Exercise		
exercise regularly	87.02	87.13
don't exercise	12.98	12.87
Alcohol consumption		
don't drink much	72.38	75.05
drink much	27.62	24.95
Self-assessed Health		
excellent	16.74	16.11
very good	31.58	31.80
good	35.26	35.72
fair	12.29	12.16
poor	4.13	4.21
Observations	2904	2377

Source: Panel Study of Income Dynamics (PSID), wave 2005, and own calculations

Note: The table shows the distribution of the behavioral indicators and self-assessed health on the household level in the PSID sample.

Definitions: Smoking: either head and/or spouse currently smokes. *Body Mass Index (BMI):* maximum of head's and spouse's individual BMI (BMI = mass(kg) / height(m)^2), classified into categories according to the U.S. Department of Health & Human Services. *Exercise regularly:* either head and/or spouse doesn't do at least once a week light exercise that leads to moderate increases in heart rate. *Alcohol consumption:* either head and/or spouse has more than 2 drinks a day.

recent data as possible while avoiding the huge disruptions in the housing market in later years I therefore use wave 2005 to construct my sample.[21]

Since the sample composition in the PSID is different to HRS I redefine the behavioral indicators to account for the younger sample. The smoking indicator is set to one if a person currently smokes. Moreover, alcohol consumption is now

[21] As a robustness check I conduct my analyses also on the other waves. Appendix B contains a detailed description of the sample selection, variable definition, and robustness checks.

Table 8: Financial Variables in PSID

	all obs		home owners	
	mean	std.dev.	mean	std.dev.
net worth	372	1248	434	1363
house value	188	231	230	236
income	76	105	83	114
illiquid share	0.82	0.22	0.85	0.18
LTV	0.43	0.33	0.43	0.33
Observations	2904		2377	

Source: Panel Study of Income Dynamics (PSID), wave 2005, and own calculations

Note: The table shows descriptive statistics for the financial variables. Net worth, house value and income are in Tsd. US$.

Definitions: Net worth: directly obtained from supplemental wealth files. *House value:* directly obtained from main family files. *Income:* total household non-capital income, i.e. the sum of head's and spouse's labor income, pension income, and transfer income. *Illiquid share:* net value of all illiquid assets divided by overall net worth, where illiquid assets consist of home equity, vehicles, retirement accounts, other real estate, business and farming assets, and other assets minus other debt. *Loan-to-value ratio (LTV):* sum of outstanding balances on first and second mortgage divided by house value of the main residence.

represented by a dummy that indicates if an individual has more than 2 drinks a day. Furthermore, the dummy of no regular exercise is defined as less than once a week light exercise that leads to moderate increases in heart rate. Table 7 shows the distribution of the indicators. Moreover, Table 8 gives descriptive statistics for financial variables of interest.

All the behavioral indicators are health related and bad health can be expected to affect current and future health expenditures as well as human capital. To eliminate this channel I therefore control for self-assessed health status in the regression. Since I also control for income I therefore control for all health related effects that have already materialized. I cannot exclude, however, that there might still be remaining effects on *expected* health expenditures and future income. This is one reason why I am not identifying causal effects but merely analyzing conditional correlations. As far as possible, however, the health channel is controlled for in computing these correlations. As before, I also control for

Table 9: Conditional Correlations in PSID

	(1) log(net worth)	(2) ill. share	(3) log(house)	(4) LTV
smoke	−0.370***	0.001	−0.174***	0.012
	(0.062)	(0.010)	(0.036)	(0.015)
BMI				
overweight	0.019	0.014	−0.031	0.018
	(0.063)	(0.012)	(0.038)	(0.015)
obese	−0.301***	0.035***	−0.121***	0.078***
	(0.073)	(0.012)	(0.043)	(0.016)
no exercise	−0.068	0.010	−0.040	0.005
	(0.079)	(0.012)	(0.046)	(0.017)
drink much	−0.064	−0.002	−0.031	0.018
	(0.059)	(0.010)	(0.033)	(0.013)
log(income)	0.851***	−0.012	0.547***	0.044***
	(0.049)	(0.008)	(0.027)	(0.010)
Self-assessed Health				
very good	−0.068	−0.008	−0.032	0.017
	(0.070)	(0.013)	(0.039)	(0.017)
good	−0.213***	0.001	−0.076*	0.037**
	(0.073)	(0.013)	(0.041)	(0.017)
fair	−0.516***	−0.001	−0.209***	0.059**
	(0.099)	(0.017)	(0.058)	(0.023)
poor	−0.116	0.004	−0.050	0.005
	(0.140)	(0.025)	(0.088)	(0.033)
Observations	2904	2904	2377	2377
R^2	0.484	0.080	0.349	0.362

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Panel Study of Income Dynamics (PSID), wave 2005, and own calculations

Note: Conditional correlations of financial variables with behavioral indicators in the PSID sample, obtained by OLS with additional control variables: age, marital status, race, education, and family size.

standard demographics.

Table 9 shows how the behavioral signs of poor self control relate to overall net worth, the share of illiquid assets in net worth, the value of owner-occupied housing and the loan-to-value ratio (LTV). People who show signs of poor self control have less overall net worth. At the same time, they have a higher share of illiquid assets in their portfolio. Furthermore, home owners with signs of poor self control have houses with lower value and have a higher LTV. This suggests that people with signs of poor self control have smaller houses but leverage more when they choose their mortgage. Note that these effects are big. In particular, they are of the same magnitude as the effect of having only a high school degree instead of a college degree.

I therefore conclude that there are unobserved determinants of the housing and mortgage positions that explain a considerable portion of the variation in these variables. These unobserved variables are correlated with behavior that is typically associated with lack of self control. In the remainder of the paper I therefore build a structural model to explicitly analyze the effects of self control on the housing and mortgage choice.

III.2 Structural Life-Cycle Model

In this section I describe the structural model that I use to analyze the effects of self control on the housing and mortgage choice. First, I describe how I model costs of self control and show what the main driving forces are in this preference specification. Second, I describe the life-cycle model of housing and mortgages.

III.2.1 Preference Specification

To model costs of self control I assume that households have Dynamic Self Control Preferences (Gul and Pesendorfer, 2001, 2004). Before applying these preferences to the life-cycle model of housing and mortgages, in this subsection I describe the preferences and its main driving forces. It is instructive to keep these results in mind when analyzing the life-cycle model of portfolio choice.

Dynamic Self Control (DSC) Preferences capture the idea that agents are subject to temptation and suffer from costs of self control if they want to resist this temptation. In this paper, agents receive utility from nondurable consumption C and housing services H. The detailed functional form of the per period utility is as follows:

$$U(C,H) = u(C,H) + \lambda \cdot \Big(u(C,H) - \max_{\{\tilde{C},\tilde{H}\}\in B} u(\tilde{C},\tilde{H}) \Big) \tag{18}$$

It can be seen that the per period utility consists of two terms. The first term refers to the felicity the agent receives from consuming a consumption bundle $\{C, H\}$. The second term shows that the agent has to exercise self control in order to implement this choice of consumption bundle. In particular, the agent is always to tempted to maximize his *current* period utility, i.e. to choose the consumption bundle $\{\tilde{C}, \tilde{H}\}$ within his budget set B that would render the highest felicity in this period. However, agents typically do not maximize their current felicity but instead maximize their discounted *life-time* utility. Hence, the term $\Big(u(C,H) - \max_{\{\tilde{C},\tilde{H}\}\in B} u(\tilde{C},\tilde{H})\Big)$ is typically negative and represents the costs of exercising self control. The parameter λ governs how severe the temptation is. This is the central parameter to this specification of DSC preferences. If λ is equal to zero then the self control term drops out and per period utility simplifies to standard preferences without problems of self control. As λ increases, however, the costs of self control become more severe.

It is important to notice that DSC preferences are defined not only over the actually chosen consumption bundle but over the whole budget set B. Specifically, the most tempting option within the budget set directly enters the utility. In order to understand the behavior of DSC agents it is therefore crucial to understand how their current actions affect their future budget set and hence their future costs of self control. To illustrate the different driving forces of DSC preferences it is instructional to consider a simple dynamic consumption-savings optimization problem without housing:

$$\begin{aligned} V(X) &= \max_{C\in B} U(C) + \beta \cdot V(X') \\ &= \max_{C\in B} u(C) + \lambda \cdot \Big(u(C) - \max_{\tilde{C}\in B} u(\tilde{C}) \Big) + \beta \cdot V(X') \end{aligned} \tag{19}$$

where X is available cash-on-hand that follows a law of motion $X' = (1+r)S$ and S are savings. The budget set B is defined by the constraint that $C + S \leq X$. Optimizing over savings leads to the following Euler Equation:

$$-(1+\lambda)\frac{\partial u(C_t)}{\partial S_t} = \beta \cdot \left[\frac{\partial u(C_{t+1})}{\partial S_t} + \lambda \cdot \left(\frac{\partial u(C_{t+1})}{\partial S_t} - \frac{\partial \left(\max_{\tilde{C} \in B_{t+1}} u(\tilde{C}_{t+1}) \right)}{\partial S_t} \right) \right] \tag{20}$$

From equation (20) we see that the problem of self control has two effects on the behavior of DSC agents: First, as can be seen on the left-hand-side, the marginal utility of giving up consumption is increased which makes the agent effectively more impatient.[22] This effect is what I refer to as *impatience effect*. Second, on the right-hand-side, the effects of current choices on future costs of self control enter the optimality condition. In particular, the agent takes into account that his current choices change tommorrow's budget set B_{t+1}. This in turn affects tommorrow's temptation. I call this second effect *anticipation effect*. Note that in this illustrative example there was only one choice variable which was continuous. The anticipation effect will become even more important, however, when discrete choices are considered such as buying a house instead of renting or defaulting on a mortgage. The reason is that these discrete choices lead to non-convex changes in future budget sets.

From the introduction of DSC preferences in this section we thus make two observations. First, the preferences are defined on the whole budget set of the agent, not only on the actions actually taken. It is hence crucial to identify the most tempting option in the choice set since all possible actions are evaluated against this temptation. Second, there are two driving forces behind DSC preferences: an impatience effect and an anticipation effect. The optimal decision will

[22] An equivalent way of expressing this effect would be to divide the equation by $(1+\lambda)$ so that the effective discount factor would be $\beta/(1+\lambda) \leq \beta$.

trade off these two effects.

III.2.2 Model of Housing and Mortgages

The model I use to analyze the effects of present bias on the housing and mortgage choice is a life-cycle model of optimal household behavior. The agents optimize their consumption and portfolio choices over the life-cycle for given prices.[23] All agents are born in period $t = 1$ and live for T periods. They work for the first T^R periods of their lives and are in retirement for the last $T - T^R$ periods.

There are three types of assets in this model: Liquid savings S, houses H, and mortgages M. Liquid savings are risk free and can be used for saving. However, there is no unsecured borrowing in this model so liquid savings can never be negative. The second type of assets, houses, serve two purposes. On the one hand, agents receive utility from consuming housing services. The felicity function has the following form:

$$u(C, H) = \frac{\left(C^{1-\theta} H^{\theta}\right)^{1-\sigma}}{1-\sigma} \tag{21}$$

On the other hand, houses are an illiquid form of investment. The illiquidity is modeled in the sense that if agents decide to sell their house this transaction will only take place with a delay of one period. This is in contrast to liquid savings which can be spent immediately. The third class of assets, mortgages, can be used to finance the purchase of a house. These mortgages are modeled as 30-year fixed rate mortgages so that the repayment schedule is explicitly modeled. As with the house size, the agents have a truly continuous choice of mortgage size but have to satisfy two constraints: First, there is a loan-to-value constraint (LTV) such that the agent can only borrow up to a certain fraction of the house value. The second constraint is a loan-to-income constraint (LTI) which restricts the mortgage to be smaller than a maximum multiple of the agent's income.

[23]Throughout the paper I will use the terms *agent* and *household* interchangebly since I abstract from inter-household optimization.

To isolate the effect of preferences I abstract from stochastic price changes. The only source of uncertainty in the model therefore is idiosyncratic shocks to the household income. The income process is modeled following Carroll (2001) to feature both permanent and transitory shocks around a deterministic, hump-shaped life-cycle profile. The income process during working life has hence the following form:

$$Y_{it} = \bar{Y}_{it} \cdot V_{it} \tag{22}$$

$$\bar{Y}_{it} = G_t \cdot \bar{Y}_{it-1} \cdot N_{it} \;, \qquad t = 1...T^R \tag{23}$$

The income Y_{it} of household i in period t can be decomposed in a permanent income compenent $\bar{Y}_{it}$ and a mean one transitory shock $V_{it} \sim \log N(-\sigma_V^2, \sigma_V)$. The permanent income component follows a random walk with drift, where G_t determines the hump-shaped life-cycle profile and $N_{it} \sim \log N(-\sigma_N^2, \sigma_N)$ is an idiosyncratic permanent shock.[24] During retirement there is no income uncertainty anymore and the agents receive a fraction ς of their permanent income in the last working life period:

$$Y_{it} = \varsigma \cdot \bar{Y}_{iT^R} \;, \qquad t = T^R + 1...T \tag{24}$$

The choice set of the agents differs whether they own a house or not. If they do not own a house, they can either keep renting or they can buy a house. If they have a house, on the other hand, they have the possibility to either keep their house and keep repaying their mortgage, refinance their mortgage, default on their mortgage, or sell their house.[25] In the next subsections I will describe

[24] Since this model is a model of optimal household behavior, period t is at the same time a specific age of the household since all agents are born in period $t = 1$. For simplicity, I will express all equations in terms of t but could equivalently be written in terms of age.

[25] In reality, another option of home owners is to access their home equity by taking out a home equity line of credit (HELOC). However, Campbell and Hercowitz (2009) find in data from the Survey of Consumer Finances in the years 1983-2001 that the total use of this product never exceeded 1.5 percent of the home value. At the same time, almost half of all outstanding mortgages in 2001 had already been refinanced. Since in my model I abstract from changing mortgage rates, the purpose of both refinancing and HELOC would be to extract home equity. I therefore chose to model only the more widespread option.

the different optimization problems in detail.

Problem of a Renter If the agent enters the period as a renter he has the choice to keep renting or to buy a house. If he keeps renting he solves the following optimization problem:

$$V_t^{rent}(X_t) \;=\; \max_{S_t,H_t} \;\; U(C_t,H_t)+\beta\cdot \mathsf{E}\left[V_{t+1}^{noh}(X_{t+1})\right] \tag{25}$$

$$\text{s.t.} \qquad C_t = X_t - S_t - P_t^R\cdot H_t \tag{26}$$

$$X_{t+1} = S_t(1+r_S)+Y_{t+1} \tag{27}$$

Given the only state variable cash-on-hand X_t he has two continuous choice variables: Savings S_t and house size to be rented H_t. Equation (26) determines the implied nondurable consumption C_t where P_t^R is the rental price of one unit of housing services. Next period, the agent will enter the period still without a house and with cash-on-hand X_{t+1} which is determined according to the law of motion in equation (27), where r_S is the interest rate on liquid savings.

If the agent chooses to buy a house instead of renting, his optimization problem is the following:

$$V_t^{buy}(X_t) = \max_{S_t,\bar{H},M_t} U(C_t,\bar{H})+\beta\cdot \mathsf{E}\left[V_{t+1}^{house}(X_{t+1},\bar{H},M_{t+1},1)\right] \tag{28}$$

$$\text{s.t.} \qquad C_t = X_t-(1+\delta_B)\cdot P_t^H\bar{H}+(1-\delta_M)\cdot M_t - S_t \tag{29}$$

$$M_t \le \phi_v\cdot P_t^H\bar{H} \tag{30}$$

$$M_t \le \phi_y\cdot \bar{Y}_t \tag{31}$$

$$X_{t+1} = S_t(1+r_S)+Y_{t+1} \tag{32}$$

$$M_{t+1} = M_t(1+r_M) \tag{33}$$

There are now three continuous choice variables: liquid savings S_t, the size of the house to buy $\bar{H}$, and the size of the mortgage M_t. Equations (30) and (31) represent the restrictions on the mortgage size: The ratio of mortgage to house value cannot exceed the fraction ϕ_v which is the maximum loan-to-value ratio. Moreover, the loan-to-income restriction implies that the mortgage balance must not exceed a multiple ϕ_y of the agent's current permanent income. Equations (32) and (33) lastly give the laws of motion for cash-on-hand and the mortgage balance, respectively. Note that in the period in which the mortgage is taken out the agent does not make a mortgage payment such that next period's mortgage balance is equal to the current balance subject to the mortgage rate r_M.

Finally, the decision to buy a house or to keep renting is determined by which behavior renders the higher value. The value of entering the period without a house can hence be summarized as follows:

$$V_t^{noh}(X_t) = \max \left\{ V_t^{rent}(X_t), V_t^{buy}(X_t) \right\} \tag{34}$$

Problem of a Homeowner An agent who enters the period as a homeowner has four different possibilities: he can keep the house and keep repaying his mortgage, he can refinance his mortgage, decide to sell the house, or default on his mortgage. If he decides to keep his house and keep repaying his mortgage then he has to solve the following optimization problem:

$$V^{repay}(X_t, \bar{H}, M_t, a) = \max_{S_t} \quad U(C_t, H) + \beta \cdot \mathsf{E}\left[V^{house}(X_{t+1}, \bar{H}, M_{t+1}, a+1)\right] \tag{35}$$

$$\text{where} \qquad C_t = X_t - Q(M_t, a) - \psi_M P_t^H \bar{H} - S_t \tag{36}$$

$$X_{t+1} = S_t(1 + r_S) + Y_{t+1} \tag{37}$$

$$M_{t+1} = (M_t - Q(M_t, a))(1 + r_M) \tag{38}$$

He enters the period with four state variables: cash-on-hand X_t, the size of his house $\bar{H}$, the balance of his outstanding mortgage M_t, and the age of his mortgage a (the number of periods since the mortgage has been originated). The agent makes the mortgage payment Q which is required to repay the mortgage on schedule. Since both the term of the mortgage and the mortgage rate are fixed, the mortgage payment is uniquely determined by the outstanding mortgage together with the age of the mortgage according to the following formula:[26].

$$Q(M,a) = \frac{M}{1+r_M} \cdot \kappa_a \ , \qquad a \geq 1 \tag{39}$$

$$\text{where} \qquad \kappa_1 = \frac{r_M}{1-(1+r_M)^{-\tau}} \tag{40}$$

$$\kappa_a = \frac{\kappa_{a-1}}{1+r_M-\kappa_{a-1}}, \quad a = 2, ...\tau \tag{41}$$

$$\kappa_a = 0, \quad a > \tau \tag{42}$$

where τ is the fixed term of the mortgage. Equation (36) states that consumption is equal to remaining cash-on-hand after mortgage payment Q, maintenance costs ψ_M and liquid savings S_t have been made. The only choice variable in this situation is hence the amount of liquid savings S_t. Next period he will enter with the same house but a lower mortgage (equation (38)) which is one period older.

If the agent decides to refinance his mortgage, however, he faces the following optimization problem:

$$V^{ref}(X_t, \bar{H}, \bar{M}) = \max_{S_t, M_t} U(C_t, \bar{H}) + \beta \mathsf{E}\left[V^{house}(X_{t+1}, \bar{H}, M_{t+1}, 1)\right] \tag{43}$$

$$\text{s.t.} \qquad C_t = X_t - \psi_M P_t^H \bar{H} + (1-\delta_M)M_t - \bar{M} - S_t \tag{44}$$

$$M_t \leq \phi_v \cdot P_t^H \bar{H} \tag{45}$$

$$M_t \leq \phi_y \cdot \bar{Y}_t \tag{46}$$

$$X_{t+1} = S_t(1+r_S) + Y_{t+1} \tag{47}$$

$$M_{t+1} = M_t(1+r_M) \tag{48}$$

He has to choose the optimal balance of a new mortgage and liquid savings based

[26] For a derivation of this formula see Appendix C

on his state variables cash-on-hand X_t, the house size he owns $\bar{H}$ and the old mortgage balance outstanding $\bar{M}$. He repays this existing mortgage and takes out the new one subject to transaction costs (see equation (44)). As in the case when he buys a house, the new mortgage balance has to satisfy both LTV and LTI constraints (equations (45) and (46), respectively). Next period, he will enter with the same house but a new mortgage which will be one period old. Note that the agent does not have to take out a new mortgage if he decides to refinance. Instead, he can choose to simply repay his mortgage and not to take out a new one.[27]

The third possibility of a home owner is to sell his house. As mentioned earlier, houses are illiquid assets which cannot be sold immediately. Instead, the agent has to decide to sell the house in the current period, but the transaction only takes place with a delay of one period. In other words, the house is sold during the transition from the current period to the next. In particular, this implies that in the current period, the agent still has to pay maintenance costs and to make the mortgage payment required to repay the mortgage on schedule. Next period, he will then enter as a renter with his cash-on-hand increased by the proceeds from selling the house. In detail, the problem of an agent who sells his house is the following:

$$V^{sell}(X_t, \bar{H}, M_t, a) = \max_{S_t} \quad U(C_t, \bar{H}) + \beta \mathsf{E}\left[V^{noh}(X_{t+1})\right] \tag{49}$$

$$\text{s.t.} \qquad C_t = X_t - \psi_M P_t^H \bar{H} - Q(M_t, a) - S_t \tag{50}$$

$$\begin{aligned} X_{t+1} = \; & S_t(1 + r_S) + Y_{t+1} + (1 - \delta_S) P_{t+1}^H \bar{H} \\ & - (M_t - Q(M_t, a))(1 + r_M) \end{aligned} \tag{51}$$

From equations (49) and (50) it can be seen that in the period the agent decides to sell, he still gets utility from his house and he also still has to pay maintenance

[27] This is equivalent to taking out a new mortgage with zero balance.

costs and make the required mortgage payment. Equation (51) details the law of motion for cash-on-hand which is increased by the proceeds from the house sale after transaction costs δ_S and after repaying the outstanding mortgage. Note that the agent will enter the next period as a renter and will be able to buy another house immediately. In particular, if he wants to upsize or downsize he can do that by deciding to sell in this period and by buying the desired house size next period.

The last option of a home owner is to default on his mortgage. If he decides to do so five things happen. First, he immediately loses his house and hence has to rent in this period. Second, his mortgage balance is set to zero so that he does not have any debt anymore. Third, he suffers from the stigma of defaulting which reduces his utility in the period of default. Fourth, he will be excluded from the housing market for a random number of periods. Lastly, if he had positive home equity in the house prior to default, he will receive the proceeds from the house sale next period if there is anything left after the mortgage has been repaid. However, since the sales price of a foreclosed home is typically lower than for a normal sale, the transaction costs will be higher in case of default than in case of selling. The optimization problem of a defaulting household looks as follows:

$$V^{def}(X_t, \bar{H}, M_t) = \max_{S_t, H_t} U\left((1-\eta)C_t, (1-\eta)H_t\right) + \beta\left((1-\omega)\mathsf{E}\left[V^{ex}(X_{t+1})\right] + \omega\mathsf{E}\left[V^{noh}(X_{t+1})\right]\right) \tag{52}$$

$$\text{s.t.} \quad C_t = X_t - P_t^R \cdot H_t - S_t \tag{53}$$

$$X_{t+1} = S_t(1+r_S) + Y_{t+1} + \max\left[0, (1-\delta_D)P_{t+1}^H\bar{H} - M_t(1+r_M)\right] \tag{54}$$

where η is the stigma effect which reduces the utility agents receive from consumption in the period of default. From equation (52) it can be seen that the agent will reenter the housing market only with probability ω. With probability $(1-\omega)$, however, the agent will still be excluded next period and hence does not have the option to buy a house:

$$V^{ex}(X_t) = \max_{S_t, H_t} \quad U(C_t, H_t) + \beta \left((1-\omega)\mathsf{E}\left[V^{ex}(X_{t+1})\right] + \omega \mathsf{E}\left[V^{noh}(X_{t+1})\right]\right) \quad (55)$$

$$\text{s.t.} \qquad C_t = X_t - P_t^R \cdot H_t - S_t \quad (56)$$

$$X_{t+1} = S_t(1 + r_S) + Y_{t+1} \quad (57)$$

Overall, just like in the case of a renter, a home owner will choose the option which gives the highest value:

$$V_t^{house}(X_t, \bar{H}, M_t, a) = \max \Big[V_t^{repay}(X_t, \bar{H}, M_t, a),\ V_t^{ref}(X_t, \bar{H}, M_t), \\ V_t^{sell}(X_t, \bar{H}, M_t, a),\ V_t^{def}(X_t, \bar{H}, M_t)\Big] \quad (58)$$

III.3 Self Control and Housing and Mortgage Choice

In this section I describe the effects of temptation and self control on the housing and mortgage choice. First, I describe the parameterization of the model. Second, I show that in the calibrated model self control has economically sizable effects on the housing and mortgage choice and that these effects are in line with the empirical findings. Third, I analyze how an increase in the minimum down payment requirement or the option to refinance affect the behavior and welfare of agents with costs of self control.

Table 10 contains all parameter values used in the benchmark model. Note that the shown values are annual values. My model period is 3 years. The analysis starts at age 20 and agents live for exactly 20 periods, i.e. until age 80.

Market Environment The risk free rate is set equal to the mean 1-year Treasury Constant Maturity rate over the period 1972-2006, adjusted for inflation using the Consumer Price Index (CPI). The mortgage rate is the mean real rate on 30-year conventional fixed rate mortgages in the same time period. For the

Table 10: Parameter Values in Benchmark Model

Parameter		Value	Source
Preferences			
risk aversion	σ	2	
discount rate	ρ	0.06	
weight of housing services	θ	0.20	Piazzesi et al. (2007)
stigma effect	η	0.2	
degrees of self control	λ	$\{0, 0.05, 0.10, 0.15\}$	
shares of self control types		$\{0.25, 0.5, 0.2, 0.05\}$	HRS 2010
Market Environment			
risk free rate	r_S	0.018	1-year Treasury Const. Mat.
mortgage rate	r_m	0.04	30-year Conv. Mort. rate
house price growth rate	r_H	0.016	All trans. house price index
rental price-to-house price ratio	$\frac{P_t^R}{P_t^H}$	0.04	Davis et al. (2008)
maintenance cost of housing	ψ_M	0.012	Kaplan and Violante (2013)
transaction costs when buying	δ_B	0	Hsieh and Moretti (2003)
transaction costs when selling	δ_S	0.06	Hsieh and Moretti (2003)
transaction costs for mortgage	δ_M	0.03	Berndt et al. (2012)
transaction costs when defaulting	δ_D	0.27	Campbell et al. (2011)
expected years of exclusion		7	Fair Credit Reporting Act
income process			Cocco et al. (2005b)
minimum down payment	ϕ_v	0.035	FHA requirement
max mortgage payment to income		0.43	FHA requirement
refinancing possible?		no	

house price growth rate I computed the mean growth rate in the All Transactions House Price Index for the United States in the same time period, adjusted for inflation. This results in a mean growth rate of 0.016.

Davis et al. (2008) find that the mean rent-price-ratio is between $0.04 - 0.05$ using data from the Decennial Census of Housing. Since the rent-price-ratio tends to decrease towards the end of their sample (1960 - 2000, extrapolation until 2005) I set P^R equal to 0.04.

For the transaction costs when buying or selling a house I refer to Hsieh and Moretti (2003) who find that the commission charged by real estate agents is 6% of the sales price. I assume that these costs are fully paid by the seller and hence set $\delta_B = 0$ and $\delta_S = 0.06$. Campbell et al. (2011) further study the discount that applies when a house is sold after foreclosure and find that the sales price is 27% lower on average than the price for a normal sale. I hence set $\delta_D = 0.27$. To set the transaction costs of taking out a mortgage I consider two studies: Berndt et al. (2012) report the mean fee paid to the mortgage broker to be 3.1% of the principal amount for subprime mortgages during the period 1997 - 2006. Woodward and Hall (2012) find a similar number in their sample of FHA insured mortgages in 2001. I therefore set the transaction costs for taking out a mortgage to be $\delta_M = 0.03$.

The LTV and LTI restrictions are crucial for the mortgage choices in my model. To set their benchmark values I turn to official regulations in the US. For home buyers to be eligible for FHA insurance, they have to at least invest 3.5% of own funds into the purchase (see US Department of Housing and Urban Development (2011)). I use this value as the minimum down payment requirement. Furthermore, for home buyers to qualify for FHA insurance, the FHA requires a mortgage payment-to-income-ratio of at most 31% and the ratio of total obligations-to-income not to be higher than 43% (see US Department of Housing and Urban Development (2011)). Since mortgage debt is the only debt in my model, I choose to set the maximum LTI constraint in accordance with the latter number. Lastly, if a house is foreclosed by law this event will remain on the credit report of the home owner for 7 years (see Fair Credit Reporting Act (Federal Trade Comission, 2011)). I therefore set the probability of leaving the exclusion state such that on average the agent is excluded for 7 years.

Preference Parameters The only preference parameter which can be set exogenously is the weight of housing services in the utility function (θ). Due to the functional form of the felicity function, I know that for a standard agent, the weight will be equal to the optimal expenditure share on housing. Piazzesi et al.

(2007) estimate this expenditure share on data from the Consumer Expenditure Survey. I therefore set θ equal to their estimate of 0.2.

To the best of my knowledge there is no empirical estimate for the self control parameter λ or an established way of choosing it. To set the range that I use in my analysis I therefore follow Krusell et al. (2009) who determine the consequences of temptation and self control by two hypothetical welfare considerations. For each value of λ I compute how much better off the agent would be if 1) he was relieved of his costs of self control but could not alter his choices and 2) he was relieved of his costs of self control and could also alter his choices. I express both hypothetical welfare increases in terms of consumption equivalent, i.e. the percentage increase in consumption and housing services in each period that would make a self control agent as well off as if he was in situation 1) or 2). I report both consumption equivalents in the results of the model to get a feeling for the magnitude of the problem. This ensures that the chosen values are not too extreme to be of empirical relevance. Moreover, to calibrate the model I assume that there are four types of agents in the population who differ in their degree of self control. I set the population share of each type according to the distribution of the self control measures in the HRS data.[28]

The remaining preference parameters have to be calibrated: risk aversion parameter (σ), the discount rate (ρ), and the stigma effect (η). For the risk aversion parameter I use $\sigma = 2$ and for the discount rate the value of $\rho = 0.06$. Both values are within the range commonly used in and estimated for life cycle models (see e.g. Gourinchas and Parker, 2002b). For the stigma effect I use a value of $\eta = 0.20$.

Refinancing Option For the benchmark model I assume that refinancing is not possible. Without refinancing home equity is truly illiquid and houses can be used as a commitment device. In a model with refinancing, however, home

[28]See appendix E for how the the population shares were determined.

Table 11: Fit of the model

Panel A:	age < 35			35 ≤ age < 50			50 ≤ age < 65		
	p25	median	p75	p25	median	p75	p25	median	p75
House Value (owners)									
data	60	88	134	65	102	163	58	95	154
model	75	97	129	74	105	150	70	107	161
LTV (owners)									
data	0.54	0.75	0.88	0.29	0.54	0.75	0.00	0.21	0.51
model	0.16	0.55	0.66	0.41	0.51	0.59	0.04	0.21	0.34

Panel B:	Net Worth			ownership
	p25	median	p75	rate
data	1	19	88	0.50
model	1	37	83	0.58

Definitions: *Data moments:* Source: SCF (1989 - 2010), constructed by a synthetic cohort approach and controlling for time effects. Cohorts are defined by the coarse age groups and observations consist of the weighted statistics of all individuals in each cohort-time pair. *Model moments:* Statistics computed from the simulation of 10,000 households. Education Groups according to PSID 2005 (10% no high school, 60% high school, 30% college graduates); distribution of self control problems according to measure in HRS 2010 (25% standard agents, 50% small costs ($\lambda = 0.05$), 20% medium costs ($\lambda = 0.10$), 5% large costs ($\lambda = 0.15$)); distribution of initial wealth according to SCF; education group, self control problem and initial wealth assumed to be independent.

equity becomes instantly accessible so that houses are no longer a commitment device. In reality refinancing is of course possible. However, while accessing home equity through refinancing is faster than through selling the house, it is not instantaneous. People have to contact and meet possible several mortgage brokers, compare offers, etc. In that sense both the model specification with and without refinancing are limiting cases. I chose to analyze the model without refinancing as benchmark because illiquidity of home equity is an essential feature of the housing and mortgage decision. I then compare this benchmark model to the model with refinancing. By doing so I am able to show how important the use of houses as a commitment device is for agents with costs of self control.

Fit of Benchmark Model Table 11 shows the fit of the benchmark model. Panel A compares the median and interquartile range of house value and LTV ratio in the simulation with the corresponding data moments in the Survey of Consumer Finances. I targeted the medians for different age groups and show the interquartile ranges to see the overall fit. For age groups $35-50$ and $50-65$ the model fits the data well. For the age group < 35 the model slightly underpredicts LTV ratios and overpredicts the house values. Turning to panel B we see the overall fit for net worth and the home ownership rate. The model predicted interquartile range for net worth fits the data very closely. The ownership rate is slightly higher in the model than in the data.

III.3.1 Results of the Benchmark Model

Table 12, panel A shows the quantitative effects of the problem of self control in the benchmark model where refinancing is not possible and the minimum down payment is 3.5%. The first two columns refer to the welfare effect of self control problems described above, namely how much better off an agent would be if he was relieved of costs of self control but couldn't change his behavior (CE1) and if he could also revise his behavior (CE2). For the large costs of self-control ($\lambda = 0.15$), for example, the welfare increase if the agent was relieved of his problems of self control would be equivalent to an increase in consumption and housing services of 1.75% in each period, if he was allowed to revise his choices of 2.23%. While these welfare effects of self control are sizable, they are not unreasonably large. Moreover, it can be seen that the welfare costs of an agent with large costs are more than twice as big as those of someone with low costs ($\lambda = 0.05$).

Columns 3-7 give the effects of self control on the behavior of the households relative to the behavior of the standard agent. These effects have been constructed by simulating the model separately for each degree of self control. First, I simulate

Table 12: Effects of self control in simulation

	Welfare Costs of Self Control		Effects of Self Control on Behavior					Welfare Effect of Policy
	CE1	CE2	net worth (all)	owner-ship rate	illiquid share (own)	house value (own)	LTV (own)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Benchmark Model								
$\lambda = 0$								
$\lambda = 0.05$	0.77	0.82	-0.12	-0.06	0.03	-0.02	-0.00	
$\lambda = 0.10$	1.38	1.58	-0.31	-0.13	0.04	-0.04	0.00	
$\lambda = 0.15$	1.75	2.23	-0.47	-0.25	0.05	-0.06	0.00	
Panel B: Down Payment $\geq 20\%$								
$\lambda = 0$								0.00
$\lambda = 0.05$	0.55	0.61	-0.14	-0.07	0.03	-0.02	0.00	-0.20
$\lambda = 0.10$	0.87	1.13	-0.36	-0.17	0.05	-0.04	0.01	-0.43
$\lambda = 0.15$	0.82	1.50	-0.56	-0.34	0.06	-0.07	0.01	-0.70
Panel C: Refinancing Possible								
$\lambda = 0$								-0.25
$\lambda = 0.05$	0.94	1.02	-0.21	-0.07	0.01	-0.02	0.05	-0.05
$\lambda = 0.10$	1.60	1.94	-0.40	-0.18	0.01	-0.04	0.10	0.09
$\lambda = 0.15$	1.80	2.64	-0.61	-0.37	0.01	-0.06	0.15	0.15

Definitions: Welfare Costs of Self Control: CE1: How much better off would you be if you were relieved of your self control problem but were not allowed to change your choices?; *CE2*: How much better off would you be if you were relieved of your self control problem and could change your choices?; both CE1 and CE2 expressed in terms of each period's percentage increase in consumption of nondurable goods and housing services;
Effects of Self Control on Behavior: mean difference in individual behavior if degree of self control is changed from $\lambda = 0$ (standard agent) to the respective degree of self control;
Welfare effect of policy: Welfare consequences of policies in terms of consumption equivalent, i.e. percentage change in consumption of nondurable goods and housing services in each period (without changing the costs of self control) that would make the agent as well off under the implemented policy as he would have been without the policy (i.e. a negative consumption equivalent implies higher expected utility under the policy)

$10,000$ households assuming that all households are standard agents ($\lambda = 0$). Then I take the same housholds (same initial wealth, same income shocks) and simulate them again three more times where the only difference is that now all households have either $\lambda = 0.05$, $\lambda = 0.10$ or $\lambda = 0.15$. Columns 3-7 show the mean individual percentage difference between these simulations and the one for the standard agents.

From column 3 we can see that the overall net worth decreases with the degree of the self control problem. For example, agents with a low costs of self control ($\lambda = 0.05$) have on average 11.7% less net worth than standard agents. For households with large costs ($\lambda = 0.15$) this effect increases to a reduction in net worth of almost 50%. The reason for this negative effect is simply that saving is more costs if agents have costs of self control and hence they optimally save less.

Next, in column 4 we see that the ownership rate decreases with the problem of self control. The average home ownership rate over all age groups decreases by 5.6% for low costs of self control and by 25% for large costs. The reason is as follows. Due to the impatience effect buying a house is more costly for agents with costs of self control since the required down payment leads to costs of self control in the purchasing period. On the other hand, investing in the illiquid asset reduces the future costs of self control since home equity cannot be spent immediately and hence the agent can save without being tempted to spend his savings each period. Houses hence serve as a commitment device so that from the perspective of the anticipation effect the agent prefers buying a house. That the ownership rate declines with the problem of self control implies that overall the impatience effect dominates.

Furthermore, we see from table 12, column 5 that home owners with costs of self control have illiquid shares that are between 2.7% and 5.4% higher than those of standard agents. The reason for the higher illiquid share is that liquid savings are especially hard for agents with costs of self control since they are tempted to spend all liquid assets each period. Home equity, on the other hand, is not immediately accessible and therefore doesn't lead to temptation. Agents with costs of self control will hence reduce liquid savings more than illiquid savings.

Column 6 refers to the effects of self control on the housing choice. We see that the house value is on average between 2% and 6% lower for agents with costs of self control than for standard agents. The reason for this result is that houses are less useful to agents with problems of self control. Houses are durable goods which give a constant stream of utility, but due to the impatience effect the discounted utility stream is less valuable with costs of self control. Moreover, again due to the impatience effect, optimal retirement savings are lower. This implies that the agents need less investment as retirement savings in the house. Overall this means that agents with costs of self control optimally choose a smaller house size.

Column 7 shows that in the benchmark model there are no effects of self control on the LTV ratio. this implies that impatience effect and anticipation effect exactly cancel out. From the perspective of the impatience effect down payments are costly and hence self control agents prefer smaller down payments which imply higher LTV ratios. At the same time, since refinancing is not possible in this benchmark model, the agent not only can avoid the temptation to spend existing home equity. As long as default is not tempting, making the mortgage payment, i.e. saving in the illiquid asset, doesn't lead to costs of self control either. Having a mortgage therefore also serves as commitment device. To ensure that default is not tempting and the commitment device is effective the agent's mortgage payment cannot be too high relative to the utility he gets from the house each period. In other words, the mortgage payment cannot be too high relative to the house size. The anticipation effect hence again works against the impatience effect by limiting the optimal mortgage size. The results in column 7 show that impatience effect and anticipation effect canel out as long as refinancing is not possible.

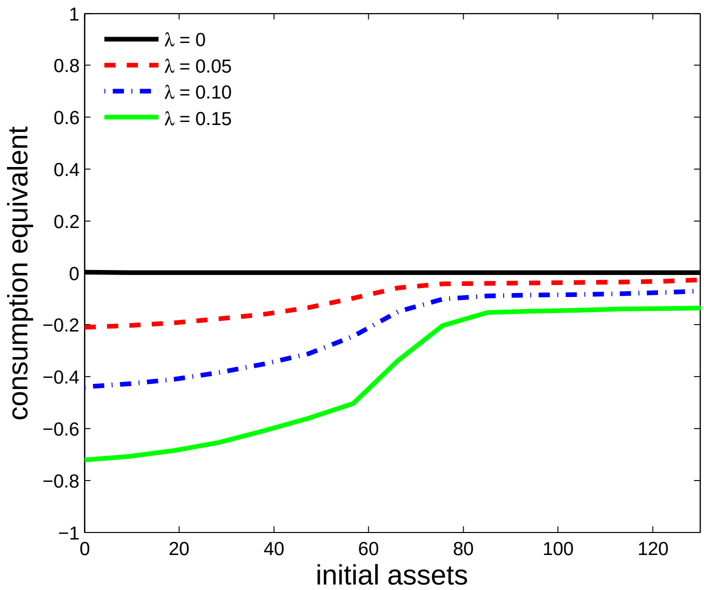
III.3.2 Increase in Minimum Down Payment Restriction

The first policy experiment is to increase the minimum down payment restriction from its benchmark value of 3.5% to 20%. Or in other words, the LTV restriction is tightened. For a standard agent this has only one consequence: it reduces his choice set. A standard agent can hence never be better off due to this restriction. Either, the agent would not have chosen a down payment smaller than the new minimum requirement in the first place. In this case this agent's welfare would not be affected by the restriction at all. Or, on the other hand, if the agent would have chosen a down payment smaller than the new requirement, then this agent would now be constrained and hence worse off.

On the contrary, for agents who suffer from costs from self control this is not the only effect. Restricting the choice set also reduces the temptation that they face. With a very low minimum down payment restriction they could afford to buy a big house with a the small minimum down payment which is tempting. And resisting this temptation is costly. If this minimum down payment is increased, the temptation that they face is reduced in each period that they consider buying a house or want to up- or downsize. DSC agents hence have both positive and negative welfare consequences of a minimum down payment restriction. Ex ante it is not obvious if the agents will be better or worse off. I will now first show how the policy changes the effects of self control on the behavior. Afterwards I will discuss the welfare consequences of the policy.

Table 12, Panel B shows the effects of self control on the behavior under the new policy. Relative to the standard agent, agents with problems of self control accumulate another 3% - 9% less net worth than in the benchmark model and the effect of the restriction is bigger the larger the costs of self control. This is also true for the home ownership rate. While in the benchmark model costs of self control reduced the ownership rate by 5% to 25% these effects increase to reductions of 7% - 34% if the minimum down payment is increased. This is not surprising since higher down payments lead to higher costs of self control in the purchasing period due to the impatience effect. This makes buying a house more costly and hence fewer people buy a house. Moreover, if people do not buy a house then they also do not have access to the commitment device. This makes

Figure 5: Welfare Effect of Increased Minimum Down Payment Requirement (20%)



Note: Welfare effect of increase in minimum down payment from 3.5% to 20%. Depicted are the welfare consequences for different degrees of self control λ: Black solid line depicts the profiles for standard agents ($\lambda = 0$), the red dashed line for agents with low costs of self control $\lambda = 0.05$, blue dash-dotted line for medium costs of self control ($\lambda = 0.10$), and the solid green line for agents with a large costs of self control ($\lambda = 0.15$).

Definitions: Consumption equivalent: percentage change in consumption of nondurable goods and housing services in each period (without changing the costs of self control) that would make the agent as well off under the implemented policy as he would have been without the policy (i.e. a negative consumption equivalent implies higher expected utility under the policy).
Initial assets: assets held at the beginning of the model (age 20), excluding income.

saving harder so that they accumulate less net worth.

Figure 5 shows the welfare effect of the increase in minimum down payment against the level of assets agents hold at the beginning of the analysis (age 20). The welfare effect is shown in terms of a consumption equivalent, i.e. the percentage increase in consumption and housing services in each period that would make the agent as well off under the new policy as he would have been before. If this value is below zero the agent is hence better off under the policy, if it is positive he is worse off. Table 12, column 8 further gives the overall welfare effect, i.e. the consumption equivalent weighted by the distribution of initial assets.

It can be seen that the welfare of the standard agent is hardly affected by this tightened restriction. This implies that the standard agents are not restricted by the increased minimum down payment requirement. Agents with costs of self control, however, unambiguously benefit from a higher down payment requirement. We have seen in table 12 that the tightened LTV restriction forces them to change their behavior. Fewer households buy houses and they accumulate less net worth. Nevertheless, we see in figure 5 that the reduction in temptation more than outweighs the negative effects of the restricted choice set. This is particularly true for agents with low initial assets who are less likely to become home owners but are constantly tempted to buy a house by taking out a large mortgage. But agents with problems of self control are better off across all wealth levels. This implies that even agents who are forced to increase their down payment are better off since their temptation is reduced. Overall, the consumption equivalent of the effect of the increased minimum down payment on the welfare of self control agents is between -0.2% for a low costs and -0.7% for a large costs of self control. This implies that the agents would be willing to give up between 0.2% and 0.7% of consumption and housing services each period to keep the higher minimum down payment.

Moreover, note that the effects of self control on the welfare of agents are smaller and than the benchmark model (see table 12, columns 1 and 2). While in the benchmark model relieving agents of their problem of self control would increase their welfare by an equivalent of 0.8% to 2.2% increase in consumption each period, under the increased minimum down payment restriction these effect are reduced to 0.6% to 1.5%. In this sense the inequality in welfare between different degrees of self control is reduced by the policy.

To summarize, the welfare consequences differ depending on whether agents have costs of self control or not. While the standard agent is unaffected by the restriction, agents with costs of self control unambiguously benefit from the restriction. These benefits are stronger for poorer households. Moreover, the inequality in welfare between agents with different degrees of self control is reduced by an increased minimum down payment restriction.

III.3.3 Possibility to Refinance

The second policy experiment is to give the agents the possibility to refinance their mortgage. In this case home equity is no longer an illiquid asset since in each period it can be accessed by refinancing the mortgage. For the standard agent the effect of this change is again unambiguous. Their choice set is increased so that the standard agent can never be worse off. Only in the extreme case where he would never refinance at all could his welfare be unaffected, otherwise he will be better off.

For agents with a problem of self control this is again not the only effect. While they also benefit from facilitated adjustment of their leverage, they now suffer from the temptation of spending their home equity each period. Houses and mortgages are no longer commitment devices so that they can no longer be used to avoid costs of self control. As in the previous policy experiment I will first discuss how refinancing changes the effects of self control on the behavior of agents. Afterwards, I will discuss the welfare consequences of refinancing.

Table 12, panel C contains the effects of self control on the behavior of agents if refinancing is possible. First, we see that the ownership rate decreases more strongly with costs of self control compared to the benchmark model. The reason is that now houses are no longer commitment devices. Saving in form of home equity is hence no longer easier than saving in liquid assets. This implies that the anticipation effect loses importance for the tenure choice. Self control hence affects the purchase decision only through the impatience effect.

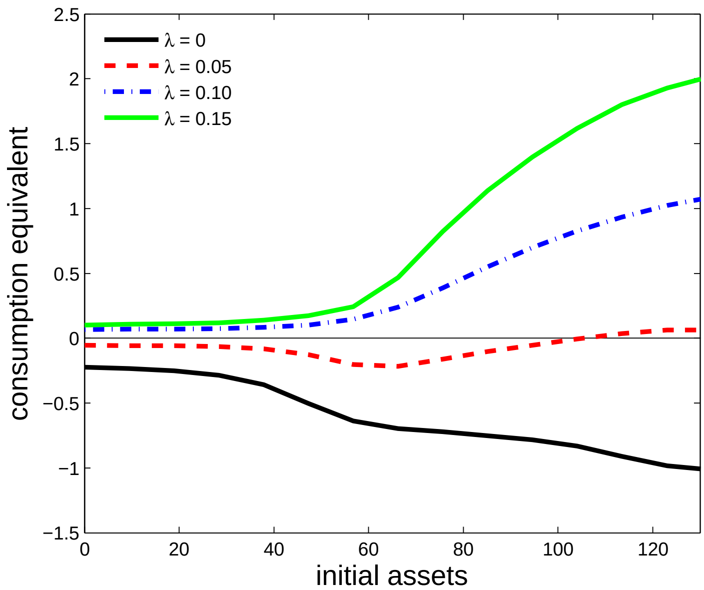
Moreover, neither renters nor owners have access to a commitment device in the model with refinancing. Saving is hence harder for everyone who has costs of self control. This can be seen in the effects of self control on overall net worth: Net worth decreases more strongly with costs of self control than in the benchmark model where home owners could benefit from the commitment device.

Lastly, in the model with refinancing we now see that there are effects of self control on the LTV ratio. The LTV ratio increases by 5% for low costs and by 15% for high costs of self control. The reason for this is again that the anticipation effect is no longer important for the housing and mortgage decision. Without refinancing the agents could use mortgages as a commitment device as long as default was not tempting. This lead to an upper bound for the mortgage relative to the house size. With refinancing, however, the agents will be tempted to access and spend their home equity through refinancing. This temptation is independent of the size of the mortgage payment and hence the anticipation effect is not important when agents decide about their mortgage size. Again only the impatience effect remains so that agents with costs of self control prefer smaller down payments which lead to higher LTV ratios.

Figure 6 shows the welfare consequences of the possibility to refinance. As expected, standard agents are unambiguously better off if refinancing is possible. They benefit from the possibility to easily adjust their leverage and to use their home equity to smooth income shocks. The benefits are bigger the wealthier the household since a wealthier household wants to have a bigger house and hence benefits more if the larger home equity becomes easily accessible.

For self control agents, however, there is again the additional effect of change in temptation. If refinancing is possible houses and mortgages are no longer commitment devices so that temptation is increased. This effect is also stronger the wealthier the household since wealthier households are more likely to be home owners and hence to use the commitment device if it is available. In figure 6 we see that for medium and large costs the increased temptation outweighs the facilitated use of home equity for consumption smoothing for all wealth levels. For

Figure 6: Welfare Effect of Possibility to Refinance



Note: Welfare effect of introducing the possibility to refinance. Depicted are the welfare consequences for different degrees of self control λ: Black solid line depicts the profiles for standard agents ($\lambda = 0$), the red dashed line for agents with low costs of self control $\lambda = 0.05$, blue dash-dotted line for medium costs of self control ($\lambda = 0.10$), and the solid green line for agents with a large costs of self control ($\lambda = 0.15$).

Definitions: Consumption equivalent: percentage change in consumption of nondurable goods and housing services in each period (without changing the costs of self control) that would make the agent as well off with the possibility to refinance as he would have been without (i.e. a negative consumption equivalent implies higher expected utility if refinancing is possible).

Initial assets: assets held at the beginning of the model (age 20), excluding income.

small problems, however, the welfare consequences differ between wealth groups. While poorer households benefit slightly, wealthier households are worse off if refinancing is possible. From table 12 we see that agents with low costs would be willing to give up 0.05% of consumption and housing services in each period to keep the possibility to refinance; agents with medium and large costs would have to be compensated by an increase of 0.09% and 0.15% to reach the welfare they have if refinancing is not possible.

Looking again at the welfare consequences of a problem of self control (table 12, columns 1 and 2) we see that welfare effects are stronger if refinancing is possible. Relieving agents of their self control problem would increase their welfare by an equivalent of 1% to 2.6% of consumption each period which is more than in the benchark model. The possibility to refinance hence increases the inequality in welfare between agents with different degrees of self control.

As in the first policy experiment the welfare consequences hence differ depending on whether a households has costs of self control or not. Standard agents unambiguously benefit from the increased choice set. Agents with costs of self control, however, can be worse off with refinancing if their costs of self control are sufficiently high. Moreover, this welfare loss is higher for wealthier households since they would benefit the most from housing and mortgages as commitment devices. Overall, the inequality in welfare between agents with different types of self control is increased by making refinancing possible.

III.4 Conclusion

In this paper I show that self control has sizable effects on the housing and mortgage choice and that welfare consequences of financial regulation depend on the degree of self control. In these analyses I abstract from responses of other market participants, e.g. of banks, rental markets or the housing sector and I do not take risk in house prices or mortgage rates into account. An alternative approach to analyze the questions I ask in this paper would hence be to cast the model in a general equilibrium setting, allowing banks to set interest rates or modeling the housing supply in order to obtain market clearing prices. However, introducing other agents into the model could only be done at the cost of significantly simplifying the mortgage contract or the housing choice. Given the interest of regulators worldwide, I decided to study effects on mortgage and housing decisions in detail rather than general equilibrium effects. Having said that, I expect the results of the current analysis to prevail in an extended model. For households with costs of self control any policy not only affects their actual choices but also the temptation that they face. This is important for assessing if policy measures are welfare improving or not.

Moreover, I show that wealth affects the degree to which policy measures influence people's welfare. For example, poorer agents benefit particularly from an increase in the minimum down payment requirement. They are less likely to actually become home owners but have to constantly resist the temptation to buy a house fully financed by a mortgage. On the other hand, wealthier agents benefit the most from using houses as commitment device and are hence harmed the most when home equity becomes easily accessible through refinancing. When designing financial regulation this interaction with wealth is another aspect to take into account.

Finally, the analyses in this paper suggest that housing is not an ideal commitment device. On the one hand, I show that the commitment motive plays a significant role when agents with costs of self control make their housing and mortgage decisions. On the other hand, buying a house involves substantial costs such down payments and transaction costs which have to be paid up-front. To make these payments people either have to save beforehand or they have to reduce their consumption at the time that they buy the house. Both is harder for people with costs of self control. The results from the calibrated model reveal that overall this second effect dominates so that people with higher costs of self control are less likely to afford the up-front costs to get access to the commitment device housing. At the same time, lowering the down payment requirement to make accessing the commitment device easier does not help people with costs of self control either because they get direct utility from the commitment device housing. Reducing the down payment implies that they are now constantly tempted to buy a bigger house which would give high immediate utility. In the calibrated model I show that while lower down payments increase the likelihood that people with costs of self control become home owners, the welfare loss due to the increase in temptation outweighs these benefits. This suggests that houses are not an ideal commitment device. Instead, if a commitment device does not give immediate utility then having easy access to it cannot increase the temptation people face. Commitment devices such as a savings plan which do not give direct utility can therefore be expected to be more beneficial for agents with costs of self control.

Appendix

A Empirical Analysis of Health and Retirement Study (HRS)

The University of Michigan Health and Retirement Study (HRS) is a longitudinal panel study that surveys a sample representative of the US population over the age of 50. It has been running since 1992 and reinterviews the subjects every two years. Over the years, new cohorts are added to keep the sample representative. It is important, however, that each cohort contains individuals which are of age 50 or older. In each wave, the interview consists of the main interview as well as a set of experimental modules which vary between the waves. While all individuals answer the main questionnaire, each interviewee only answers a subset of these test modules.

Wave 2010 contains a test module called "Personality" that asks the subjects to assess how much self control they have. I obtain the data from this module and merge it to the RAND HRS data set which is a user-friendly version of the HRS provided by the RAND Center for the Study of Aging. The personality module was answered by overall 1251 individuals. Of these individuals, only 18 are classified as underweight according to their BMI. Due to the small size of this subsample I choose to drop those observations. Moreover, I drop another 12 observations because of missing data on some of the variables in my analysis. This leaves a sample of 1221 individuals.

B Empirical Analysis of Panel Study of Income Dynamics (PSID)

The Panel Study of Income Dynamics (PSID) is a longitudinal household survey directed by the University of Michigan that has been following families and their descendants since 1968. Until 1997 families were reinterviewed each year and since then are interviewed biannually. At the time of this change more information has been added to the survey, in particular data about the families' assets and wealth as well as health information. Regarding the health information, there have been addional changes to the questions asked since wave 2005.

B.1 Sample Selection

In this paper I am interested in the housing and mortgage decisions of households and how these decisions are affected by problems of self control. I hence want to maximize the information in my behavioral indicators. This means that I want to focus on waves 2005 and later. At the same time, there have been huge disruptions in the housing market from 2007 onwards. Since this project does not aim to explain these disruptions the data from 2007 is not ideal for my analyses. I hence use wave 2005 for my main analysis, but conduct robust checks with respect to the other waves.

In my analysis I exclude observations which belong to the Survey of Economic Opportunity (SEO) sample which was added to the representative sample in order to increase the information on low income households. Furthermore, I restrict the sample to families with a male head. The reason for that is the special way in which PSID determines the head of a household. In particular, as soon as there is a male adult living in the household he is head irrespective of his income or position in the household. This implies that there are not many families with female heads in the sample and that this group is a very special subsample. Since there are not enough observations to conduct a separate analysis for this group

I choose to exclude them. Another very small and special group in the data is people with a BMI that indicates that they are underweight. Since these are likely to suffer from a serious disease and not a mere problem of self control I exclude these observations. This would give a sample size of 3945 observations.

Moreover, I exclude observations with improbable or missing data. In particular, I exclude families with total income, i.e. the sum of all labor income, pensions, and all transfers, below the poverty guideline for a family of that size (228 observations).[29] Furthermore, I exclude observations who state that the value of their house is below 10,000 US$ (38 observations). I also drop observations with missing data on any of the variables in my analysis (392 observations).

Lastly, I make two additional restrictions. First, I exclude households with negative overall net worth (304 observations). The reason for this restriction is that the behavior of these indebted households likely differs from the behavior of normal households. Second, I exlude observations with an illiquid share outside the interval $[0, 1]$ (further 79 observations). In these cases either the illiquid net worth or the liquid net worth is negative, even though the total net worth is positive. The illiquid share does therefore not purely reflect investment preferences which is why I exclude these cases. I conduct robustness checks with respect to these two restrictions.

The final sample therefore consists of 2904 observations, of which 2377 are home owners.

B.2 Variable Definition

Respondents in the survey are directly asked for the value of their house as well as the principal outstanding on the first and second mortgage on that property. I use the sum of the two mortgage principles as the measure for mortgage balance.

[29]Poverty guidelines are a federal poverty measure which is used to determine financial eligibility of federal programs. They are issued each year in the Federal Register by the Department of Health and Human Service and can be obtained from their website.

The loan-to-value ratio (LTV) is then computed as mortgage balance divided by house value.

The data for total net worth and for the illiquid share are obtained from the supplemental wealth files. Total net worth is directly taken from these files while the illiquid share is constructed in the following way. Illiquid share is equal to the net value of all illiquid assets divided by overall net worth. Illiquid assets consist of home equity, vehicles, retirement accounts, other real estate, business and farming assets, other assets (such as life insurance) minus other debt (such as student loans). Unfortunately, the categories of other assets and other debt also include decidedly liquid assets such as bond funds and credit card debt. I therefore conduct robustness checks where I exclude these categories from illiquid assets.

Income is defined as the total household income. That means that all components are summed up for both head and wife. Components are labor income (including from business or farm), pensions (including annuities and veterans' pension) and transfer income (including alimony). Note that all variables denoted in US$ are deflated to year 2000 using the Consumer Price Index (CPI).

The indicator for self-assessed health is taken as the worse of self-assessed health levels among head and spouse. The interviewees were asked to assess their health on the following scale: 1 = "excellent, 2 = "very good", 3 = "good", 4 = "fair", 5 = "poor".[30]

B.3 Robustness Checks

Different Years I conducted the analyses described in the main text not only on my main sample year, 2005, but on all waves 1999 - 2007. All results are robust throughout all waves. It can be seen, however, that for the earlier waves (1999 and 2001) the results are even stronger for the illiquid share (both smoking

[30] I also conducted all analyses with number of diagnosed chronic diseases instead of self-assessed health. The results remain unchanged.

and BMI show significantly positive correlations) while the LTV results are less strong in these waves (smaller magnitude but still significant). This suggests that in the run-up to the crisis in the housing and mortgage market problems of self control are even more strongly correlated with higher mortgages. Higher mortgages lead ceteris paribus to higher LTVs and to lower home equity, hence to somewhat lower illiquid shares in overall net worth.

Net Worth as additional control In the main analysis I do not control for net worth when analyzing illiquid shares, house value or LTV ratio. In order to gain a more thorough picture of the effects of self control on the portfolio composition I also conduct the analyses with net worth as additional control. Table 13 shows the results from the main analysis once net worth is also being controlled for. This does not alter the positive correlation between signs of a problem of self control and the illiquid share. Both with and without controlling for net worth people who show these signs tend to have a higher illiquid share in their portfolio. Once net worth is controlled for the correlation between LTV and self control is less strong. It remains significant for wave 2005 but is not robust over all waves.

The most interesting insights are gained in the housing regression. Both with and without controlling for net worth problems of self control are correlated with lower house values. Since the illiquid share is higher and home equity is the most common illiquid asset this seems puzzling at first glance. Further analysis reveals, however, that the likelihood of owning a house for a given value of net worth is higher for people with a problem of self control. Hence they are more likely to own a house but they then tend to own less valuable houses.

Include Indebted Households In the main analyses, households with negative total net worth and households with illiquid shares outside $[0, 1]$ were excluded. The reason for these restriction is that households who are indebted

Table 13: Robustness Check for Conditional Correlations in PSID: Net worth as additional control

	(1) illiquid share	(2) log(house value)	(3) LTV
smoke	0.011	−0.082***	−0.019
	(0.010)	(0.030)	(0.013)
BMI			
overweight	0.013	−0.023	0.015
	(0.012)	(0.032)	(0.013)
obese	0.043***	−0.022	0.044***
	(0.012)	(0.036)	(0.015)
no exercise	0.011	−0.033	0.003
	(0.012)	(0.038)	(0.016)
drink much	−0.001	−0.021	0.015
	(0.010)	(0.029)	(0.012)
log(income)	−0.034***	0.345***	0.113***
	(0.008)	(0.025)	(0.010)
log(net worth)	0.026***	0.325***	−0.110***
	(0.004)	(0.014)	(0.005)
Self-assessed Health			
very good	−0.006	−0.015	0.011
	(0.013)	(0.033)	(0.015)
good	0.007	−0.016	0.016
	(0.013)	(0.035)	(0.015)
fair	0.012	−0.057	0.007
	(0.017)	(0.048)	(0.021)
poor	0.007	−0.017	−0.006
	(0.025)	(0.073)	(0.030)
Observations	2904	2377	2377
R^2	0.101	0.532	0.494

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Panel Study of Income Dynamics (PSID), wave 2005, and own calculations

Note: Conditional correlations of financial variables with behavioral indicators in the PSID sample, obtained by OLS with additional control variables: age, marital status, race, education, and family size.

can be expected to act systematically different to households who have positive wealth. Moreover, if the illiquid share is outside $[0, 1]$ then either liquid wealth or illiquid wealth is negative which makes the interpretation of the ratio difficult. In the main analysis I therefore excluded these observations. To see how robust my

Table 14: Robustness Check for Conditional Correlations in PSID: Include indebted households

	(1) log(net worth)	(2) ill. share	(3) log(house)	(4) LTV
smoke	−0.348	−0.054	−0.167***	0.012
	(0.241)	(0.036)	(0.035)	(0.014)
BMI				
overweight	0.129	0.030	−0.024	0.017
	(0.254)	(0.042)	(0.038)	(0.015)
obese	−0.648**	0.034	−0.117***	0.080***
	(0.292)	(0.045)	(0.043)	(0.016)
no exercise	0.029	−0.016	−0.044	0.002
	(0.285)	(0.033)	(0.046)	(0.017)
drink much	−0.231	0.010	−0.026	0.020
	(0.245)	(0.032)	(0.032)	(0.013)
log(income)	2.234***	−0.070***	0.560***	0.038***
	(0.180)	(0.018)	(0.027)	(0.010)
Self-assessed Health				
very good	−0.753**	−0.021	−0.032	0.016
	(0.295)	(0.043)	(0.038)	(0.017)
good	−0.821***	0.015	−0.079**	0.038**
	(0.292)	(0.037)	(0.040)	(0.017)
fair	−1.596***	0.022	−0.220***	0.066***
	(0.391)	(0.036)	(0.056)	(0.023)
poor	−1.710***	0.019	−0.047	0.005
	(0.608)	(0.041)	(0.085)	(0.033)
Observations	3287	3287	2493	2493
R^2	0.224	0.012	0.350	0.378

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Panel Study of Income Dynamics (PSID), wave 2005, and own calculations

Note: Conditional correlations of financial variables with behavioral indicators in the PSID sample, obtained by OLS with additional control variables: age, marital status, race, education, and family size.

results are to the restrictions I conduct the same analyses on an extended sample which also includes indebted households and/or households with unconventional illiquid shares. Table 14 shows the results from the main analysis once these observations are not excluded.

The results for overall net worth and the house value are hardly affected by this change in any wave. The effects on the LTV are also fairly robust over the different waves if the indebted households are included. In the earlier waves (1999 and 2001) the correlations are less significant but they remain strongly significant from 2003 onwards. The results for the illiquid share, on the other hand, only remain significant for the earlier waves (1999 and 2001). However, the less strong results are not surprising since negative net worth implies that the illiquid share does not even have to be close to the interval $[0,1]$ so that the meaning of this variable becomes unclear.

Alternative Definition of Illiquid Assets The way in which PSID collects data about assets unfortunately groups both liquid and illiquid assets into the categories "other assets" (both bond funds and life insurance policies) and "other debt" (both credit card debt and student loans). As a robustness check I compute the analysis of the illiquid share also if these two categories are excluded from the definition of illiquid assets, as can be seen in table 15. The result that the illiquid share is higher for smokers and people who are obese is robust to this change. Note however, that once these two categories are exluded from illiquid assets many more observations have negative illiquid assets which makes the interpretation of the illiquid share difficult. Column (2) reports the regression results once observations with an illiquid share outside $[0,1]$ are excluded. In that case the results are again similar in magnitude to the the results when "other assets" and "other debt" are included in the definition of illiquid assets.

Table 15: Robustness Check for Conditional Correlations in PSID: Alternative defintion of illiquid assets

	(1) illiquid share	(2) illiquid share
smoke	−0.012	0.015
	(0.028)	(0.013)
BMI		
overweight	0.017	0.025*
	(0.029)	(0.014)
obese	0.088***	0.040**
	(0.034)	(0.016)
no exercise	0.009	−0.004
	(0.032)	(0.016)
drink much	0.030	−0.014
	(0.028)	(0.013)
log(income)	−0.008	−0.009
	(0.019)	(0.009)
Self-assessed Health		
very good	−0.017	−0.021
	(0.031)	(0.015)
good	0.023	−0.019
	(0.034)	(0.016)
fair	0.085	−0.030
	(0.068)	(0.022)
poor	0.007	−0.035
	(0.049)	(0.034)
Observations	2904	2237
R^2	0.034	0.072

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Panel Study of Income Dynamics (PSID), wave 2005, and own calculations

Note: Conditional correlations of financial variables with behavioral indicators in the PSID sample, obtained by OLS with additional control variables: age, marital status, race, education, and family size.

C Derivation of Mortgage Payment

All mortgages in the model are fixed-rate mortgages. The fixed mortgage payment can hence be calculated from the initial mortgage balance M^0 according to the following formula:

$$Q = M^0 \frac{r_M}{1 - (1 + r_M)^{-\tau}} \tag{59}$$

where r_M is the mortgage rate and τ the term of the mortgage.

Since the mortgage rates are modelled as fixed, in any period during the repayment phase the mortgage payment can be recovered from the currently outstanding mortgage balance M and the number of periods since the mortgage has been originated (the age of the mortgage a) according to the formula:

$$Q(M, a) = \frac{M}{1 + r_M} \cdot \kappa_a \ , \qquad a \geq 1 \tag{60}$$

$$\text{where} \qquad \kappa_1 = \frac{r_M}{1 - (1 + r_M)^{-\tau}} \tag{61}$$

$$\kappa_a = \frac{\kappa_{a-1}}{1 + r_M - \kappa_{a-1}}, \qquad a = 2, ...\tau \tag{62}$$

$$\kappa_a = 0, \quad a > \tau \tag{63}$$

This formula can be derived in the following way: One period after the mortgage has been originated ($a = 1$) the mortgage balance has evolved according to its law of motion (equation (33)):

$$M^1 = M^0(1 + r_M)$$

$$\Leftrightarrow \quad M^0 = \frac{M^1}{1 + r_M}$$

Substituting this in equation (59):

$$
\begin{aligned}
Q(M^1, 1) &= \frac{M^1}{1+r_M} \cdot \underbrace{\frac{r_M}{1-(1+r_M)^{-\tau}}}_{\kappa_1} \\
&= \frac{M^1}{1+r_M} \cdot \kappa_1 \qquad (64)
\end{aligned}
$$

Each period afterwards ($a = 2...\tau$), the mortgage balance evolves according to the law of motion in equation (38). Substituting equation (64) in this law of motion leads to the following relationship for $a = 2$:

$$
\begin{aligned}
M^2 &= (M^1 - Q)(1+r_M) \\
&= M^1 \cdot \left(1 - \frac{1}{1+r_M}\kappa_1\right)(1+r_M) \\
&= M^1 \cdot (1 + r_M - \kappa_1) \\
\Leftrightarrow \quad M^1 &= \frac{M^2}{1+r_M-\kappa_1}
\end{aligned}
$$

Substituting this formula for M^1 back into equation (64) and remembering that the mortgage payment is constant in each repayment period we obtain

$$
\begin{aligned}
Q(M^2, 2) &= \frac{M^2}{1+r_M} \cdot \underbrace{\frac{\kappa_1}{1+r_M-\kappa_1}}_{\kappa_2} \\
&= \frac{M^2}{1+r_M} \cdot \kappa_2 \qquad (65)
\end{aligned}
$$

Successively substituting in the same way reveals that for $a = 2...\tau$:

$$\begin{aligned} M^a &= (M^{a-1} - Q)(1 + r_M) \\ &= M^{a-1} \cdot \left(1 - \frac{1}{1 + r_M}\kappa_{a-1}\right)(1 + r_M) \\ &= M^{a-1} \cdot (1 + r_M - \kappa_{a-1}) \\ \Leftrightarrow \quad M^{a-1} &= \frac{M^a}{1 + r_M - \kappa_{a-1}} \end{aligned}$$

so that

$$\begin{aligned} Q(M^a, a) &= \frac{M^a}{1 + r_M} \cdot \underbrace{\frac{\kappa_{a-1}}{1 + r_M - \kappa_{a-1}}}_{\kappa_a} \\ &= \frac{M^a}{1 + r_M} \cdot \kappa_a \qquad (66) \end{aligned}$$

Since the mortgage will be fully repaid after τ repayment periods, the mortgage payment for mortgages older than τ periods will be equal to zero. In summary we obtain the formula in equations (60) - (63).

D Data Moments

In the calibration of my model I match simulated moments to data moments. To compute the data moments I use data from the Survey of Consumer Finances (SCF) during the years 1989 - 2010. SCF weights are designed to correct for non-response while the PSID does not. Since non-response is more common for wealthier households, wealthy households are typically underrepresented in the PSID. In order to reconcile the income process from the PSID with wealth data from SCF I hence follow Heathcote et al. (2010) and adjust the SCF sample to match the wealth distribution in the PSID by dropping the wealthiest 1.47% of weighted observations (17.6% of unweighted observations) in each wave.

The moments are constructed using a synthetic panel approach. This means that I define cohorts as households with heads born in bins of birth years. For each wave I compute weighted variable medians and interquartile ranges for each cohort. These statistics are then combined for all waves which results in a synthetic panel where I have one observation for each cohort in each year.

There are systematic effects over time for all cohorts, not only but in particular for waves 2007, 2009 and 2010. Since all the variables of interest are related to the housing market this is to be expected due to the disruptions in the housing and mortgage market during the recent financial crisis. It is hence crucial to control for time effects when data moments are computed. I therefore construct the median and interquartile range reported in table 11 by controlling for time effects.

E Numerical Solution and Simulation

The model solution is obtained by backwards induction over the value functions, normalized by the permanent income component (see Carroll, 2001). All value functions except the value function when buying a house are solved by discretizing the state space and the control variables. The value function of buying is solved using the simplex method. Expectations are always approximated by Gauss-Hermite-Quadrature and I use linear interpolation to evaluate between grid points.

The effects of self control in table 12 have been constructed by simulating the behavior of $10,000$ households, separately for the different degrees of self control λ (income and initial wealth of individual households do not differ between the simulations). To approximate the distribution of education in the population I simulate 10% of the agents with the income process for households who did not finish high school, 60% who finished high school, and 30% with college degree.[31] The initial distribution of normalized cash-on-hand used in these simulations was approximated by a lognormal distribution. To obtain the mean and variance parameters for this distribution I fitted a lognormal distribution to the net worth-to-income ratio of households with heads aged 20 in the SCF in the years 1989 - 2010. As in the construction of the empirical data profiles I adjust the SCF sample to match the wealth distribution of the PSID by dropping the wealthiest 1.47% of weighted observations (17.6% of unweighted observations). Moreover, in order to exclude outliers generated by low income I drop observations with total household non-capital income below the poverty guideline for a family of that size in the given year.[32] Since the number of households with head aged 20 is very low in each wave I combine all waves when fitting the distribution.[33]

[31] The percentages were obtained from PSID in wave 2005.

[32] Poverty guidelines are a federal poverty measure which is used to determine financial eligibility of federal programs. They are issued each year in the Federal Register by the Department of Health and Human Service and can be obtained from their website.

[33] Fitting a distribution for each wave individually gives a range of parameter values which is

The degree of self control λ, the initial distribution of normalized cash-on-hand, and the education group are assumed to be independent.

To obtain the simulated moments which I match to the data moments I combine households with different degrees of self control in the following way. From the distribution of the welfare measure in the HRS data set (see figure 4). I see that 25% of individuals answer the questions in a way that suggests no problem of self control at all (< 2) since to answer with "1" indicates no costs of self control. Next, I assume someone has a low costs of self control if he answers at least one question below the middle category "3", i.e. his aggregate measure is ≥ 2 and < 3. This applies to about 50% of people. 20% of measures fall in the range ≥ 3 and < 4 which I allocate to medium costs. The last 5% of people have measures ≥ 4 which I label large costs. I therefore assume 25% of households are standard agents, 50% have small costs ($\lambda = 0.05$), 20% have medium costs ($\lambda = 0.10$), and 5% have large costs ($\lambda = 0.15$). Again, the degree of self control is assumed to be independent of education.

similar to the estimates obtained from the pooled sample.

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Housing, Mortgages, and Self Control

This paper analyzes how costs of self control affect the housing and mortgage decision of households. Empirically, households with signs of poor self control tend to own smaller houses and have a higher loan-to-value ratio. To analyze the mechanism behind this observation I build a structural life-cycle model which explicitly models costs of self control in household preferences. In the calibrated model costs of self control have economically significant effects on the housing and mortgage choice. Moreover, welfare consequences of financial regulation depend on a household's self control. I analyze the consequences of two policies: an increase in the minimum down payment requirement and the introduction of mortgage refinancing. The results reveal that whether people benefit from these policies or not depends on their costs of self control. Agents with non-zero costs of self control benefit from a substantial minimum down payment requirement. If costs of self control are high people are worse off if refinancing is possible since they can no longer use the house as a commitment device.

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