Temptation and Commitment: the Role of Housing*

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Abstract

The main goal of this paper is to quantify the importance of housing as a commitment device in the life-cycle saving and consumption decision. Modeling demand for commitment needs non-standard preferences, hence I use temptation preferences proposed by Gul and Pesendorfer (2001). Using data from the Consumer Expenditure Survey (CEX), I specify, estimate and simulate a structural life-cycle model, which incorporates temptation preferences.

In this model demand for housing asset has four sources: beside being an investment device housing asset also provides consumption, collateral and commitment services. With my estimation-based parametrisation, the model predicts that the interaction of temptation preferences, housing service in the utility function and commitment in housing induces much higher housing demand than without the commitment role of housing. Housing demand in the model economy is about 50 percent higher at its peak over the life-cycle in case housing plays commitment role.

Keywords: life cycle models; temptation preferences; housing; estimating euler-equations
JEL classification: D12; D91; E21; G11; R21

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1 Introduction

People have hard time to commit themselves to their future actions. In the consumption-savings decision context for example, they tend to save much less then what they planned to save (Bernheim (1995)). When people face self-control problems of this kind, their natural intention is to find a way to restrict their future choice set, such that they do not face the same problem in the future again. One way to restrict future choice sets is to keep savings in assets which can not be used easily for consumption purposes. We call these assets commitment devices. Recent experimental studies investigate extensively whether people have demand for commitment devices. For instance, Wartenbroch (1998) shows that people buy smaller quantities of tempting goods even when they are sold with quantity discounts. Thaler and Benartzi (2004) report evidence of people committing in advance to allocate a portion of their future salary increase towards retirement savings. Finally, Beshears et al. (2011) report evidence that people who have access to both liquid and less liquid accounts, allocate more savings on the less liquid, commitment account. In practice anything could serve as commitment device as long as it ties people's hand in some relevant decision.

In standard models of intertemporal allocation people are assumed to be fully committed to their consumption choices. It is because their choices do not depend on the decision date. They can decide on the whole life-cycle paths of consumption at the starting period or decide sequentially, consumption choices will be the same. Consequently, they do not face self-control problems and they have no demand for commitment devices. Models with standard preferences have no explanation to the 'demand for commitment' phenomena. We need to relax some assumptions of the standard models to make the model more flexible in terms of reflecting self-control problems too.

In the recent literature we can find two alternative approaches to model self-control problem and demand for commitment. The first approach starting with Strotz (1956) and addressed by Laibson (1997) and Harris and Laibson (2001) focuses on change of people's preferences occurring between periods, which leads to dynamic inconsistency. People are assumed to be independent decision-makers in each period, hence the benefit from commitment arises because todays's self desire to play against its future self. Preference change is introduced via hyperbolic discounting and self-control is not allowed in this setup. The second approach is introduced by the seminal work of Gul and Pesendorfer (2001). Instead of assuming preference change, they highlight the possibility of temptation and resulting desire for commitment. Their axiom-based preferences are dynamically consistent and also allow for temptation resistance, hence self-control. The simple recursive formulation of preferences, its dynamic consistency makes this approach very convenient, while the axiom-based representation, which generalises standard pref-

erences provides a credible theoretical background to this approach. Altogether, temptation preference approach seems to be very flexible, which is perhaps the reason why it has recently gained increasing popularity in various fields of economics.

The aim of this paper is threefold. First, I develop a dynamic structural model of consumer demand for housing and consumption with Gul-Pesendorfer temptation preferences. Temptation preferences model the possibility that people are tempted to spend all their available liquid resource on nondurable consumption goods in any period and they have to pay a cost whenever they exercise self-control. People can hold non-liquid housing asset as commitment device against temptation. Housing asset is thought of as a natural commitment device, because of its high transaction cost of adjustment. I focus on housing asset in particular because a significant fraction of household's wealth is kept in this form. Illiquidity of housing is modelled in the sense that there is a maximum fraction of housing asset which people can sell immediately- which can be liquidated. The rest of the housing asset is illiquid. Housing has four distinctive roles in the model: beside being an investment device it also provides consumption, commitment and collateral services.

Second, after specifying the model, I estimate the preference parameters of the model using the derived Euler equation on the houeshold level Consumer Expenditure Survey (CEX) dataset. In particular, I focus on estimating the elasticity of intertemporal substitution (EIS) and temptation parameter jointly. In this model setup temptation and self-control are driven by one single parameter, the temptation parameter. To the best of my knowledge, there is only two papers in which the authors estimate similar type of models with temptation preferences, Bucciol (2012) and Huang, Liu, and Zhu (2013). Bucciol (2012) estimates temptation parameter on Survey of Consumer Finances (SCF) data and finds that it is significantly different from zero. He also claims that model with temptation preferences provides a better fit to the observed US data. Huang, Liu, and Zhu (2013) also estimate the temptation parameter but they use the CEX, and obtain evidence supporting the existence of temptation preferences. In both papers, authors concentrate on illiquid assets in general, while in my paper the focus is on housing asset as the illiquid form of savings. The consequence is that the felicity function in this paper is different from theirs and has two arguments: nondurable consumption and housing service consumption which is directly derived from the housing stock.

Third, having preference parameters estimated, I quantify the importance of housing as commitment device by solving and simulating the model. As there is no closed form solution for the dynamic problem, I solve the model numerically to find optimal policy functions. Using these policy functions, I simulate the theoretical model first allowing housing asset to serve as commitment device and second setting housing asset to be fully

liquid. There are two sources of uncertainty in the model, idiosyncratic uncertainty over labor income and aggregate uncertainty over house prices, for which I draw realisations over the simulation.

I have three main results that I report in Section 3 and Section 4. First, the temptation parameter is significantly different from zero, indicating the empirical presence of temptation. Second, under temptation preferences the EIS parameter is well above one, while models with standard preferences normally produces EIS parameter below one. Third, in this model setup housing has an important role as commitment device. Tempted people try to hold most of their savings in illiquid housing asset, which decreases their temptation and consequently the cost of self-control. Quantitatively, in the presence of temptation housing demand is 50 percent higher at its peak over the life-cycle when housing asset can serve as commitment device compared to the case when it can not.

The rest of the paper is organised as follows. Section 2 presents the model framework with Gul-Pesendorfer temptation preferences and derives the Euler equation for the liquid asset, which is needed for parameter estimation. Section 3 discusses econometric issues and techniques to estimate the Euler equation on a time series of repeated cross sections. Then it describes the CEX survey data and presents estimation results, which confirms the empirical presence of temptation. Section 4 illustrates the numerical solution and simulation of the problem. It describes the simulation results, which confirms the importance of housing asset as commitment device. Section 5 concludes the paper.

2 A Life-cycle Model with Temptation Preferences

I start with a simple model of life-cycle consumption and savings in a dynamic stochastic framework. I modify this model such that it is able to capture the possible commitment motive of housing demand. Households maximise their present discounted lifetime utility, which depends on the nondurable consumption and the consumption of housing service flow. They can move resources between periods by investing in fully liquid asset or in less liquid housing asset, which also provides housing service flow. I only allow households to have collateralised debt, where housing asset could serve as collateral. Households face uncertainty in two dimensions: idiosyncratic uncertainty over labor income and aggregate uncertainty over house price. I neglect bequest motives and uncertain end of life.

2.1 Model Structure

Households live for T periods as adults. W periods as workers and $T - W$ periods as retirees. For simplicity both T and W are assumed to be exogenous. Given available recourses, households maximise lifetime utility by choosing consumption, C_t, housing investment, I_t and the net size of new mortgage, Υ_t (which is new mortgage net of repayment on old mortgage). Households can invest either in illiquid housing asset or in fully liquid asset. Housing asset yields uncertain return depending on the evolution of the house price, while liquid asset yields constant risk-free return R^X.Households start any period t with a given amount of wealth, and receives uncertain labor income, while facing both idiosyncratic income shocks and aggregate house price shocks. I define $\Omega_t = (X_t, H_t, M_t, Q_t, Y_t^P)$ as the vector of state variables and formulate the household's value function in period t in recursive form as:

$$V_t(\Omega_t) = \max_{\{C_t, I_t, \Upsilon_t\}} U(C_t, \tilde{C}_t, S_t) + \beta E_t V_{t+1}(\Omega_{t+1}) \tag{1}$$

subject to the standard intertemporal budget constraint

$$X_{t+1} \quad = \quad R^X(X_t - C_t - Q_t I_t + \Upsilon_t) + Y_{t+1} \tag{2}$$

where I follow Deaton (1991) and define cash-on-hand, X_t by the sum of liquid wealth and labor income [1]. H_t and M_t are the start period housing asset and mortgage stocks;

[1]The liquid wealth next period is the current period liquid asset with its return: $LW_{t+1} = R^X A_t$ where A_t is the liquid asset stock. Cash-on-hand is the sum of liquid wealth and labor income:$X_{t+1} = LW_{t+1} + Y_{t+1}$. The resource available current period can be spent on consumption, liquid asset savings housing investment and mortgage repayment: $X_t + \vartheta_t = A_t + C_t + Q_t I_t + \xi_t$. Combining this three equation, I get back the law of motion for cash-on-hand.

S_t is the housing service flow. Y_t is the labor income, while Y_t^P is the permanent part of labor income, realised at the beginning of period t. Q_t is the relative unit price of housing asset in terms of nondurable goods. Finally, $\tilde{C}_t$ denotes the maximum amount of asset that can be immediately liquidated.

2.1.1 Illiquid housing asset

In addition to liquid asset, households have access to illiquid housing asset that plays the most important role in the model. There are four different aspects of the housing asset that households take into account when they decide on their demand for housing asset.

First, housing asset is an investment device (investment channel). The amount of housing asset (e.g. the size of the house) is adjustable at no cost in each period. Housing investment adds up to the existing stock of housing asset, hence the law of motion for the housing asset is

$$H_{t+1} = H_t + I_t \tag{3}$$

Housing investment has uncertain return, which among other parameters depends on the evolution of the house price, Q_t. After discussing all the roles housing asset plays, I will be able to be more precise on the determinants of the return on housing asset.

Second, as housing stock generates housing service, instantaneous utility is derived from housing (consumption channel). There is no rental market in the model, so housing services are only acquired by owning. I assume that there is a linear technology between housing stock and housing service.

$$S_t = bH_t \tag{4}$$

Third, housing asset can be used as collateral for mortgage loans (collateral channel). Household can get collateralised debt at constant price of R^M up to a given fraction, $1-\psi$ of the value of the housing asset.

$$(1-\psi)Q_tH_t \tag{5}$$

where ψ can be interpreted as the down-payment requirement.

Fourth, because of its illiquidity housing could serve as commitment device (commitment channel). The illiquidity of housing is modelled in the sense that housing asset can only be liquidated up to a given fraction, δ, immediately. Otherwise, there is no

explicit liquidation cost on housing.

$$-\delta H_t \leq I_t \tag{6}$$

At any given point in time this constraint only binds for those households who would like to get out more than δ fraction of their housing wealth. For those who do not want to liquidise more than that, housing asset is basically another liquid asset.

2.1.2 Financial markets

I only allow households to have collateralised debt. Other type of debt is not available, consequently households has an incentive to take mortgage even if the mortgage rate is higher than the risk-free rate. Households with existing mortgage, M_t can apply for new mortgage, ϑ_t, but they have to keep repaying the existing mortgage. The law of motion for the mortgage stock is as follows

$$M_{t+1} = R^M M_t + \vartheta_t - \xi_t \tag{7}$$

Next period mortgage equals the existing mortgage with its interest plus the new mortgage taken out minus the repayment, ξ_t on the existing mortgage. Throughout the paper I only focus on the net new mortgage, which I define to be the new mortgage net of repayment on the existing mortgage.

$$\Upsilon_t = \vartheta_t - \xi_t \tag{8}$$

Households do not have to choose new mortgage and repayment separately. It is enough to choose the path of the net new mortgage. Solved for optimal path of net new mortgage, Υ_t, one can always solve back for ϑ_t and ξ_t. This conclusion is based on a simple and straightforward assumption: whenever the household's repayment is more than the minimum repayment, they do not apply for new mortgage. As the mortgage interest rate is set to be fix over time, there is no gain from paying back more from the old mortgage and apply for new one at the same time.

$$\begin{aligned} \vartheta_t &= \begin{cases} \Upsilon_t + \xi_{min} & \text{if } \Upsilon_t \geq -\xi_{min} \\ 0 & \text{else} \end{cases} \\ \xi_t &= \begin{cases} \xi_{min} & \text{if } \Upsilon_t \geq -\xi_{min} \\ -\Upsilon_t & \text{else} \end{cases} \end{aligned} \tag{9}$$

I assume that repayment on the existing mortgage is bounded from below. Households have to pay at least the interest on the value of the mortgage in each period. Also there

is a natural upper bound for repayment, which is paying back all the mortgage with all its interest.

$$r^M M_t \quad \leq \quad \xi_t \leq R^M M_t \tag{10}$$

As I highlighted earlier, households are assumed to face a constraint on the level of mortgage they can take out. The maximum amount of mortgage they can have is a constant fraction of the value of their housing asset.

$$\vartheta_t \begin{cases} \leq (1-\psi) Q_t H_t - R^M M_t & \text{if } (1-\psi) Q_t H_t > R^M M_t \\ = 0 & \text{else} \end{cases} \tag{11}$$

It is important to see from equation (11), that the restriction on the mortgage relative to the housing asset's value is only enforced at the moment of taking out new mortgage. As house prices do fluctuate, the constraint can be violated for households with existing mortgage as there is no mechanism through which households could insure themselves against this uncertainty. In this manner, whenever the existing mortgage exceeds the maximum possible mortgage take-out, households can not apply for new mortgage.

2.1.3 Stochastic processes

In the model households face uncertainty in two dimensions: idiosyncratic uncertainty over labor income and aggregate uncertainty over house prices.

Following Zeldes (1989), labor income Y_t at any time before retirement is exogenously described by a combination of deterministic and random components

$$Y_t = Y_t^P Z_t \qquad\qquad \log(Z_t) \sim N(-0.5\sigma_z^2, \sigma_z^2)^2 \tag{12}$$

where Y_t^P is the permanent component and Z_t is the transitory component. Furthermore I assume that the permanent component can be described as

$$Y_t^P = G_t Y_{t-1}^P N_t \qquad \log(N_t) \sim N(-0.5\sigma_n^2, \sigma_n^2) \tag{13}$$

with G_t being a deterministic function of age and N_t is the innovation. I also assume that the shocks (N_t and Z_t) are independent.

Labor income Y_t at any time after retirement is a constant fraction a of the last

[2]The assumption of log-normality with given parameters is a simplification. Under this case the mean value of N_t and Z_t becomes 1. The expected value of a log-normal variable (X_t) with mean μ and variance σ^2 is given by $\exp(\mu + \frac{\sigma^2}{2})$

working year's permanent labor income.

$$Y_t = aY_W^P \tag{14}$$

The log of the house price is assumed to be determined by an AR(1) process with linear trend

$$\log Q_{t+1} = d_0 + d_1 t + \rho_h \log Q_t + \log \varepsilon_t \qquad \log(\varepsilon_t) \sim N(-0.5\sigma_\varepsilon^2, \sigma_\varepsilon^2) \tag{15}$$

2.1.4 Utility function

The period utility function follows the theoretical, axiomatic-based temptation disutility model of Gul and Pesendorfer (2001) [3]:

$$U(C_t, \tilde{C}_t, S_t) = u(C_t, S_t) - \Big[\nu(\tilde{C}_t, S_t) - \nu(C_t, S_t)\Big] \tag{16}$$

where $u(\cdot)$ and $\nu(\cdot)$ are two von Neumann-Morgenstern utility functions. In the temptation disutility model households are tempted to maximise their current period utility instead of maximising their discounted lifetime utility. In other words households are tempted to spend all of their available liquid asset on nondurable consumption goods at each period. This alternative is referred to be the most tempting consumption alternative of all, $\tilde{C}_t$, as it maximises immediate utility. In this model the available liquid asset is the sum of cash-on-hand and the liquidisable part of the housing asset.

$$\tilde{C}_t = \arg\max_{C_t}(\nu(C_t, S_t)) = X_t + \delta Q_t H_t \tag{17}$$

When households resist temptation, utility cost of self-control is paid, which is represented by the term in the bracket of the utility function in equation (16). This cost is the difference between the temptation value of the most tempting consumption alternative and the temptation value of the chosen consumption bundle. In case household chooses the most tempting alternative, there will be no cost of temptation and the utility function simplifies to its standard form.

It is important to note that under my simplifying assumption, households can only be tempted by nondurable consumption goods at any point in time, but not in housing service consumption.

The utility, u is a CRRA function in a composite good. Nondurable consumption and housing service are aggregated with a Cobb-Douglas technology into the composite good. The temptation utility function, ν is a rescaled CRRA utility function following

[3]The formal description of the Gul-Pesendrofer temptation model is in the *Appendix 6.2*

Bucciol (2012).

$$\begin{aligned} u(C_t, S_t) &= \frac{(C_t^{\alpha} S_t^{1-\alpha})^{1-\rho}}{1-\rho} \\ \nu(C_t, S_t) &= \lambda \frac{(C_t^{\alpha} S_t^{1-\alpha})^{1-\rho}}{1-\rho} \end{aligned} \tag{18}$$

where α is the weight on nondurable consumption in the utility function, ρ is the inverse of the elasticity of intertemporal substitution (for the composite good) and λ is the degree of absolute temptation. The degree of absolute temptation measures the household's sensitivity to the tempting alternative. Notice that preferences are standard when $\lambda = 0$ and the larger λ is, the higher temptation households have to face / the higher the utility cost of self-control is.

The main attractions of the Gul-Pesendorfer approach are tractability and testability. In contrast to the hyperbolic discounting framework for example, temptation preferences are time-consistent (there are no separate selves of the same households playing against each other), which makes the analysis much simpler. On the other hand, there are implications of the model with temptation preferences that are empirically testable. There is one single parameter that distinguishes temptation model from standard model (λ) and the existence of this parameter can be tested directly.

2.2 Characterising the Solution of the Model

There is no analytical solution for the problem, so I first characterise the solution of the model with the corresponding Euler equations, which are derived in *Appendix 6.4*. Having these optimality conditions at hand, I can estimate the crucial model parameters, the elasticity of intertemporal substitution ($1/\rho$) and the temptation parameters (λ). As all the three Euler equations include these parameters of interest, I can proceed with only using one equilibrium condition. I use the Euler equation for the liquid asset

$$(1+\lambda)\alpha \frac{(c_t^{\alpha} s_t^{1-\alpha})^{1-\rho}}{c_t} = E_t \left[\beta_{t+1} R^X \left((1+\lambda)\alpha \frac{(c_{t+1}^{\alpha} s_{t+1}^{1-\alpha})^{1-\rho}}{c_{t+1}} - \lambda\alpha \frac{(\tilde{c}_{t+1}^{\alpha} s_{t+1}^{1-\alpha})^{1-\rho}}{\tilde{c}_{t+1}} \right) \right] \tag{19}$$

where

$$\beta_{t+1} = \beta \left(\frac{Y_{t+1}^P}{Y_t^P} \right)^{-\rho}$$

Following Carroll (1992), variables are normalised by permanent income and denoted by lower case letters (e.g. $c_t = C_t/Y_t^P$). [4] Dividing both sides by $(1+\lambda)\alpha$, I get

$$\frac{(c_t^{\alpha} s_t^{1-\alpha})^{1-\rho}}{c_t} = E_t\left[\beta_{t+1} R^X \left(\frac{(c_{t+1}^{\alpha} s_{t+1}^{1-\alpha})^{1-\rho}}{c_{t+1}} - \frac{\lambda}{1+\lambda}\frac{(\tilde{c}_{t+1}^{\alpha} s_{t+1}^{1-\alpha})^{1-\rho}}{\tilde{c}_{t+1}}\right)\right] \tag{20}$$

where I call $\lambda/(1+\lambda)$ the degree of relative temptation as in Bucciol (2012), which in utility terms measures the importance of temptation relative to consumption. The equilibrium condition, equation (20) shows that the marginal cost of giving up one unit of current consumption must be equal to the marginal benefit of consuming the proceeds of the extra liquid saving in the next period, minus the marginal cost of resisting the additional temptation in the next period, caused by the higher savings in liquid asset. Hence the cost of saving is higher for tempted individuals than for non-tempted ones, everything else being equal.

This Euler equation differs from standard case in two respects: traditional Euler equation is derived from a model without housing service in the utility function i.e. when $\alpha = 1$ and without temptation, obtained when $\lambda = 0$. Using these parameter setting, equation (20) simplifies to

$$c_t^{-\rho} = E_t\Big[\beta_{t+1} R^X c_{t+1}^{-\rho}\Big] \tag{21}$$

which is the traditional Euler equation that is extensively used for estimation of the EIS parameter. Note that equation (19) - similarly to equation (21) - is not a consumption function. It is an equilibrium condition, hence it can be used to derive orthogonality conditions in order to estimate the parameters of the utility function. There are at least three reasons though why it is not a good idea to estimate the nonlinear equation (19) directly, which is extensively discussed in Attanasio and Low (2004).[5] The poor asymptotic properties of the nonlinear GMM estimates in small samples, the measurement error in the data and the fact that I do not have a real panel data (only quasi panel) I need the model to be linear in parameters in order to estimate model parameters consistently.

The linearisation of the Euler equation in the presence of temptation is not straightforward. For better understanding, I present the main steps of derivation here, while the detailed derivation of the linear approximation can be found in *Appendix 6.5.* First I let market return, R^X vary over time and rewrite the Euler equation (19) for liquid

[4] See standardisation of the model in *Appendix 6.3.*

[5] Attanasio and Low (2004) show in Montecarlo simulations that for all parameter specifications, the performance of the non-linear GMM estimator is considerably worse than that of the estimators based on the log-linearized equations.

asset in terms of the pricing kernel / stochastic discount factor (SDF) as follows

$$1 = E_t k_{t+1} R^X_{t+1}$$

where the SDF is

$$k_{t+1} = \beta_{t+1}\Big(\frac{c_{t+1}}{c_t}\Big)^{-\kappa}\Big(\frac{s_{t+1}}{s_t}\Big)^{\kappa-\rho}\left[1-\frac{\lambda}{1+\lambda}\Big(\frac{\tilde{c}_{t+1}}{c_{t+1}}\Big)^{-\kappa}\right]$$

with $\kappa = 1-\alpha(1-\rho)$. Setting $\lambda = 0$ reduces the SDF to

$$k_{t+1} = \beta_{t+1}\Big(\frac{c_{t+1}}{c_t}\Big)^{-\kappa}\Big(\frac{s_{t+1}}{s_t}\Big)^{\kappa-\rho}$$

The additional term in the stochastic discount factor showing up under temptation preferences only depends on the liquid wealth-consumption ratio. Lettau and Ludvigson (2001) show that consumption and wealth share a common stochastic trend, hence they are cointegrated. It also means that their ratio is stationary. This is a crucial observation since the consequence is that all the variables in the SDF are assumed to be stationary and I can take the log-linear approximation of the stochastic discount factor around its steady state value. The resulting log-linear SDF is given by the equation (44) from *Appendix*

$$\begin{aligned}\ln k_{t+1} &= \ln\beta_{t+1} - \ln(1+\phi) - \kappa\ln\left(\frac{c_{t+1}}{c_t}\right) + (\kappa-\rho)\ln\left(\frac{s_{t+1}}{s_t}\right)\\ &+ \kappa\phi\left[\ln\left(\frac{\tilde{c}_{t+1}}{c_{t+1}}\right) - \ln\left(\frac{\tilde{c}}{c}\right)\right] + \eta_{t+1}\end{aligned}$$

where η_{t+1} includes second and higher moments of the consumption growth, the growth of housing service flow and the log of liquid wealth-consumption ratio. The parameter ϕ is a function of other model parameters

$$\phi = \frac{\lambda}{(1+\lambda)\chi^\kappa - \lambda}$$

where $\chi = \tilde{c}/c$ is the steady state ratio of liquidisable asset to nondurable consumption recovered from the available data [6] Using the linearised Euler equation

$$0 = \ln R^X_{t+1} + \ln k_{t+1}$$

[6]From CEX, I take the median value of liquidisable asset over nondurable consumption, which equals to 9. Liquidisbale asset is calculated as saving on bank accounts, bonds and securities, labor income and the δ fraction of the value of the housing asset

I can derive the estimable version of the Euler equation under temptation preferences

$$\ln\left(\frac{c_{t+1}}{c_t}\right) = \theta_0 + \theta_1 \ln R^X_{t+1} + \theta_2 \ln\left(\frac{s_{t+1}}{s_t}\right) + \theta_3 \ln\left(\frac{\tilde{c}_{t+1}}{c_{t+1}}\right) + \epsilon_{t+1} \tag{22}$$

where θ_0 contains constants and the unconditional means of second and higher moments of the relevant variables, ϵ_{t+1} summarises expectation errors, possible measurement errors and deviations of second and higher moments from their unconditional means.

$$\begin{aligned} \theta_1 &= \frac{1}{\kappa} \\ \theta_2 &= \frac{\kappa - \rho}{\kappa} \\ \theta_3 &= \phi = \frac{\lambda}{(1+\lambda)\chi^\kappa - \lambda} \end{aligned} \tag{23}$$

Equation (22) differs from the traditional Euler equation used in the empirical literature. In order to get an estimate for the elasticity of intertemporal substitution parameter the conventional method is to regress the log of the gross real interest rate on consumption growth. In my case, I have two additional explanatory variables, the growth of housing service flow and the log of the liquidisable wealth over consumption. The growth of housing service flow shows up because I add housing service flow into the utility function, while the log of the liquidisable asset over consumption enters the regression because of the presence of temptation.

Notice, that setting temptation parameter, λ to zero, equation (22) simplifies to the standard Euler equation with housing service in the utilility function

$$\ln\left(\frac{c_{t+1}}{c_t}\right) = \theta_0 + \theta_1 \ln R^X_{t+1} + \theta_2 \ln\left(\frac{s_{t+1}}{s_t}\right) + \epsilon_{t+1} \tag{24}$$

Furthermore, setting the weight of nondurable consumption in the composite good parameter, α to one, reduces κ to ρ and θ_2 to zero. Therefore equation (22) simplifies to the Euler equation derived from a model with temptation preferences but no housing service in the utility function

$$\ln\left(\frac{c_{t+1}}{c_t}\right) = \theta_0 + \theta_1 \ln R^X_{t+1} + \theta_3 \ln\left(\frac{\tilde{c}_{t+1}}{c_{t+1}}\right) + \epsilon_{t+1} \tag{25}$$

In case I set both λ to zero and α to one, the equation (22). becomes the traditional Euler equation with consumption growth on the left-hand-side and log of the gross real

interest rate on the right-hand-side.

$$\ln\left(\frac{c_{t+1}}{c_t}\right) = \theta_0 + \theta_1 \ln R^X_{t+1} + \epsilon_{t+1} \tag{26}$$

In the next section, I test all the four types of the Euler equations on real data.

3 Parameter estimation

In this section I describe that dataset I work with in the construction of variables that correspond to the model variables. I use the Consumer Expenditure Survey (CEX), which is a household-level micro dataset collected by the Bureau of Labor Statistics (BLS). CEX contains detailed information on household characteristics, on expenditures, and on income and wealth status. This survey is not a real panel, but a rotating panel as households are only interviewed at most four times over a period of year. In order to exploit the short panel dimension of CEX, I use the well-established technique of synthetic panel approach. Since CEX lacks long time series for the same households, synthetic panel approach focuses on average variables of interest for homogenous groups of households (cohorts) and follow them over time as they age.

At the end of this section I give estimates for the preference parameters of the model, more precisely for the elasticity of intertemporal substitution parameter and for the temptation parameter. Having parameters θ_1, θ_2 and θ_3 in equation (23) at hand, I can reveal the parameters of the elasticity of intertemporal substitution and the temptation parameter using delta method. Delta method approximates the standard errors of transformation of random variables using first-order Taylor approximation.

3.1 The CEX Survey

The CEX is a survey by the BLS, which interviews about 5000 households each quarter. 80 percent of them are then reinterviewed the following quarter, but the remaining 20 percent are replaced by a new, random group. Hence, each household is interviewed at most four times over a period of year. The sample is representative of the *U.S.* population. During the interviews, a number of questions are asked concerning household characteristics and detailed expenditures over the three month prior to the interview.

Household characteristics variables I consider are the family size, number of children by age groups, the marital status of the household head and the number of hours worked by the spouse. Non-durable consumption expenditure data is available on monthly basis for each household. Beside household characteristics and expenditures CEX also reports detailed information on households income and wealth status. Most importantly

there are rich information on different types of savings including rented and owned living quarters. Therefore I have information on the approximated value of the house for homeowners and the rental price for renters. These informations though are only gathered in the last interviews.

I exclude non-urban households, those households who have incomplete information on savings and/or housing from the sample. Furthermore I only keep households of which the head[7] is at least 21 and no more than 60. I ended up with 148,000 observations (interviews), for around 46,000 households for the sample period 1994q1-2010q4. I work with real data, hence I deflate all variables by the consumer price index for nondurable goods, with base-period 1982-1984.

I use the CEX data to construct the variables correspond to model variables. Except the risk-free interest rate all the variables can be extracted from CEX files.

Consumption.

I collect the available monthly expenditures data from the *Detailed Expenditures Files (EXPN)* of CEX. In order to create the consumption data, one has to decide on what items to include in there. I include all the nondurable expenditures on goods and services, except spending on education and health care. I create quarterly consumption by aggregating monthly expenditures. To avoid the complicated error structure that the timing of the interviews would imply on quarterly data, I take the spending in the month closest to the interview and multiply it by three. And last I deflate the nominal consumption by the consumer price index for nondurables with base-period 1982-1984.

Housing service flow.

Under *Detailed Expenditures Files (EXPN)*, there are two separate Files, which contains information on rented and owned living quarters. These are the so-called *Rented Living Quarters (RNT)* and *Owned Living Quarters (OPB)* files in the survey. Monthly rent is available for rented quarters, while approximated value of the house is available for the owned living quarters. I consider quarterly housing service flow as three times the reported monthly rent for renters, while I approximate quarterly housing service with 2 percent of the value of housing asset for homeowners.[8] Again, I deflate the housing service flow by the consumer price index for nondurables.

Liquidisable asset stock.

The liquidisable asset stock is the maximum amount available for consumption in any given period. In the model it is the sum of liquid assets, the quarterly labor income and δ fraction of the value of housing asset. The CEX survey collects financial and income

[7]The head is defined as the male in the male-female couple and as the reference person otherwise

[8]Own calculation based on Bureau of Economics Analysis (BEA) suggests housing service to be around 8 percents of the value of housing asset per year

information in the last interview, which can be found in the *CU Characteristics and Income File (FMLY)*. The asset categories I incorporate in liquid assets are "savings accounts", "securities as stocks, mutual funds, private bonds, government bonds or Treasury notes" and "U.S. Savings bonds". In the CEX there is information on the earned after tax income in the past 12 months, so I can easily calculate the quarterly flow of labor income by dividing that reported amount by four. The value of housing asset that can be liquidated is the δ fraction of the reported, appoximated value of the house for the home-owners and zero for renters. I set δ to be 0.5, on which parameter I experiment later on. To get real real savings stocks and after-tax income, I again deflate all variables by the consumer price index for nondurables.

Real Interest Rate and Inflation.
I use the real 3-month Treasury Bill rates to represent risk-free interest rates in the model. I take series of 3-month Treasury Bill and consumer price index for nondurables with base-period 1982-1984 from the Federal Reserve Bank of St. Louis.

3.2 Synthetic Panel Approach

As detailed in the previous section CEX lacks long time series for the same households, hence instead of using the short panel dimension of the dataset, I use synthetic panel approach to estimate the Euler equation - first proposed by Deaton (1985) and Browning, Deaton, and Irish (1985). I create a quasi-panel by identifying groups or cohorts of households with similar characteristics of the household head and I follow average variables of interest of these homogenous groups over time as they age. Hence if there are N cohorts observed for T years, this method gives us NT observations. In reality different cohorts are observed over different time horizons, hence the available synthetic panel is not balanced. Groups or cohorts are defined by the year of birth of the household head.

Cohort definition is summarised in Table 1. In the estimation I only use cohorts which have average cell size by quarter higher than 200. This restriction is used in order to reduce the sampling noise. I also impose and age limit on the cohorts, I exclude observations for cohorts whose head on average is younger than 21 years or older than 60 years. The logic behind these restrictions is simple. The optimality condition represented by the Euler equation only holds for those households who are not liquidity constrained. Households whose heads are younger than 21 years are likely to be constrained, leading the Euler equation to fail in their case. Excluding elderly households is necessary because at retirement, nondurable consumption has a discrete drop, which is not necessarily consistent with the Euler equation.

Having defined many cohorts, I can estimate a consistently aggregated version of equation (22) for all cohorts simultaneously, using appropriate instrumental variable

techniques.

$$\Delta\overline{\ln(c_{t+1})}^{g} = \theta_0 + \theta_1 \ln(1 + r^X_{t+1}) + \theta_2 \Delta\overline{\ln(s_{t+1})}^{g} + \theta_3 \overline{\ln\left(\frac{\tilde{c}_{t+1}}{c_{t+1}}\right)}^{g} + \gamma' \Delta\overline{z_{t+1}}^{g} + u_{t+1} \quad (27)$$

where superscript g denotes cohort averages. To make the model more realistic, I assume that the household's utility is shifted by a number of demographic variables, following Attanasio and Weber (1995) [9]. The vector of z_{t+1} includes all of these demographic and labor supply variables, possibly seasonal dummies.

Cohort	*Year of Birth*	*Age in 1994*	*Average Cell Size*	Used in Estimation
1	1975-79			no
2	1970-74	20-24	477	yes
3	1965-69	25-29	527	yes
4	1960-64	30-34	599	yes
5	1955-59	35-39	579	yes
6	1950-54	40-44	529	yes
7	1945-49	44-49	447	yes
8	1940-44	50-54	358	yes
9	1935-39	55-59	289	yes
10	1930-34			no

Table 1: COHORT DEFINITION

3.3 Estimation strategy and the choice of instruments

I use instrumental estimation technique for several cohorts simultaneously. Caution is necessary when choosing the appropriate instruments.

In case there is measurement error in the levels of variables, taking first differences creates $MA(1)$ structure of residuals in equation (27). But even without the presence of measurement error, taking first differences between cohort means of different subsamples leads to an MA(1) process in the residuals.[10] Consequently and by the construction of the data, I always have to count with the MA(1) error structure. Hence, the full residual in equation (27) is the sum of the white noise (expectational error and the deviation of second and higher moments of variables from their unconditional means) and the MA(1) component. Checking the first-order autocorrelations of the residuals, I conclude that the residuals are dominated by the MA(1) part. As a result, I can not use one-period

[9] Instantaneous utility function is $U_t = U(C_t) f(Z_t, \gamma)$, where I assume $f(Z_t, \gamma) = \exp(\gamma' Z_t)$

[10] If the sample for a given quarter t includes a very rich household, this will induce a positive measurement error in the consumption growth at time t followed by a negative measurement error at time $t + 1$. See *Appendix 6.6* for details on the effect of this on the variance-covariance matrix of residuals

lagged variables as instruments, however instruments lagged two or more periods gives consistent estimates.

The panel dimension of CEX also implies that adjacent cells do not include completely different households. This fact also needs careful consideration because of the following reason. Households at their first interview in time period t appear also at time $t+1$, $t+2$ and $t+3$. Those at their forth interview in time period t appear also at time $t-1$, $t-2$ and $t-3$. In the presence of household-specific fixed effects, I get inconsistent estimates if I use all the households both in the construction of the relevant variables and the instruments. Hence I need to manipulate the sample to construct the instruments such that there is no overlap between households used in the construction of the instruments and those used in the construction of the variables that enter the estimated equation. I use all observation in the construction of the variables entering our regression, but select subsamples in construction of instruments. Namely, in construction of lag 2 instruments, I use only households at the fourth interview, for lag 3 I only use households at the forth and third interview and for lag 4 instruments, I exclude households at their first interview. Using this method, one can be sure that there is no overlap between households used in the construction of variables and the construction of instruments.

Because of the presence of MA(1) residuals for each cohort and because I estimate equation (27) for nine cohorts simultaneously, the error structure of this Euler equation is quite complicated. This has to be taken into account in the construction of an efficient estimator. I present estimates of parameters in the next section with error correction, but I also provide details on the error correction strategy in *Appendix 6.6.*

3.4 GMM Estimates of parameters

In Table 2, I report the estimation results of different log-linearized Euler equations using GMM estimation for several cohorts simultaneously. Instruments are the different lags of consumption growth, nominal interest rates and household characteristics. Household characteristics are the number of family members, number of family members who are younger than 2, who are between 2 and 15, dummy for single households, dummy for labor participation of the spouse. The validity of instruments can not be rejected by *Sargan's* p-statistics. Variables that are meant to capture effects of changing family composition on the discount factor are added to each equation. In my chosen specification these are seasonal dummies, the log of the family size (famsize) and the number of children below age 2 (num2).

The first two columns in Table 2 present the results from estimating the Euler equation with standard preferences. The two models only differ in the presence of housing service

in the utility function. The last two columns in Table 2 present the results from estimating the Euler equation with temptation preferences. This two models again differ in the presence of housing service in the utility function.

VARIABLES	Coeff. in eq.(27)	$\alpha = 1$ $\lambda = 0$	$\alpha \neq 1$ $\lambda = 0$	$\alpha = 1$ $\lambda \neq 0$	$\alpha \neq 1$ $\lambda \neq 0$
$\log(1 + r^X)$	θ_1	0.928^{**}	0.805^{**}	1.901^{**}	1.697^{**}
		(0.313)	(0.330)	(0.815)	(0.794)
$\Delta \log$ (s)	θ_2		0.376		0.580^{*}
			(0.235)		(0.315)
$\log(\tilde{c}/c)$	θ_3			0.056^{*}	0.049^{*}
				(0.030)	(0.030)
$\Delta \log$ (famsize)		0.478^{***}	0.457^{***}	0.669^{***}	0.612^{***}
		(0.073)	(0.0749)	(0.120)	(0.117)
Δ (num2)		-0.527^{***}	-0.591^{***}	-0.630^{***}	-0.716^{***}
		(0.120)	(0.130)	(0.153)	(0.185)
E.I.S $(1/\rho)$		0.928^{**}	0.775^{**}	1.901^{**}	1.980
		(0.313)	(0.035)	(0.815)	(0.129)
$\lambda/(1 + \lambda)$				0.169**	0.168**
				(0.070)	(0.080)
Sargan p-stat		0.53	0.51	0.94	0.98

Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
All specifications includes a constant and three seasonal dummies. The instrument set is different across columns. Derived variables are estimated by the Delta method. α is the weight on nondurable consumption in the composite basket, and $\lambda/(1 + \lambda)$ is the relative temptation

Table 2: EULER EQUATIONS

Besides presenting the direct parameter estimates of equation (27), Table 2 also shows the approximations for the derived parameters of interest, the elasticity of intertemporal substitution, EIS and the degree of relative temptation $\lambda/(1 + \lambda)$. The EIS parameter measure the responsiveness of the growth rate of consumption to the real interest rate. In column 1 and 3 of Table 2, EIS shows this responsiveness for the nondurable consumption, while in column 2 and 4 the responsiveness for the composite consumption. As previously defined, the degree of relative temptation parameter measures the importance of temptation relative to consumption in utility terms. Again there is difference between column 3 and 4 in terms of the definition of consumption: in column 3 consumption represents nondurable consumption, while in column 4 it is the composite consumption. The standard errors for the derived parameters are approximated by applying the Delta

method.

Definition (*Delta Method*): Let $\{\mathbf{X}_N\}$ be a sequence of random vectors of dimension $k \times 1$, with

$$\begin{aligned} \mathbf{X}_N &\xrightarrow{p} \mathbf{c} \\ \sqrt{N}(\mathbf{X}_N - \mathbf{c}) &\xrightarrow{d} \mathcal{N}(\mathbf{0}, \mathbf{\Sigma}) \end{aligned}$$

and let g be continuous differentiable of dimension $k \times 1$ and $\frac{\partial g(c)}{\partial c}$ have full rank, then

$$\begin{aligned} g(\mathbf{X}_N) &\xrightarrow{p} g(\mathbf{c}) \\ \sqrt{N}(g(\mathbf{X}_N) - g(\mathbf{c})) &\xrightarrow{d} \mathcal{N}\left(\mathbf{0}, \frac{\partial g(\mathbf{X})}{\partial \mathbf{X}'}\bigg|_{\mathbf{X}=\mathbf{c}} \mathbf{\Sigma} \frac{\partial g(\mathbf{X})}{\partial \mathbf{X}}\bigg|_{\mathbf{X}=\mathbf{c}}\right) \end{aligned} \tag{28}$$

3.4.1 Elasticity of Intertemporal Substitution

The first parameter of interest is the elasticity of intertemporal substitution, which is calculated for all the four models. Under models with standard preferences presented in column 1 and 2 of Table 2, there is no significant difference in the point estimates of the elasticity of intertemporal substitution parameter. Also, the the estimated values are very similar to what others estimated in the literature. [11]

Under models with temptation preferences presented in column 3 and 4 of Table 2, the EIS parameters are estimated to be around 1.9 both for the nondurable consumption and for the composite consumption. Despite the fact that estimates are not hugely significant for precision, the high estimates for EIS are striking compared to the results of the traditional Euler estimations. In order to get an intuition why the responsiveness of consumption growth on real interest rate differs hugely under standard and temptation preferences, further considerations are in line. Let us first take the total derivative of the most standard Euler equation, equation (26) with respect to the real interest rate

$$\frac{\partial \Delta \ln(c_{t+1})}{\partial r^X_{t+1}} \approx \theta_1 \frac{\partial \ln(1 + r^X_{t+1})}{\partial r^X_{t+1}} \tag{29}$$

and the same for the Euler equation with temptation preferences, equation (25)

$$\frac{\partial \Delta \ln(c_{t+1})}{\partial r^X_{t+1}} \approx \theta_1 \frac{\partial \ln(1 + r^X_{t+1})}{\partial r^X_{t+1}} + \theta_3 \left(\frac{\partial \ln \tilde{c}_{t+1}}{\partial r^X_{t+1}} - \frac{\partial \ln c_{t+1}}{\partial r^X_{t+1}} \right) \tag{30}$$

The only difference in equation (30) compared to it's standard preference counterpart, equation (29) is the term corresponds to parameter θ_3. Hence this is the term that is responsible for the result of doubled elasticity of intertemporal substitution. Recall what

[11] see Bucciol (2012) or Gourinchas and Parker (2002)

$\tilde{c}_t$, the liquidisable wealth meant to capture

$$\tilde{c}_t = x_t + \delta Q_t h_t$$

which is the sum of the available cash-on-hand and an exogenous fraction of the value of housing asset, which can be immediately liquidated. It is important to notice that the value of housing asset is determined by the present discounted value of the future stream of housing services. As such, the value of housing asset crucially depends on the real interest rate and very sensitive to any changes in that. Also, by definition the value of housing asset affects the value of liquidisable wealth, which is an important element of the the Euler equation under temptation preferences. As a consequence, under temptation preferences real interest rate has a strong indirect effect on consumption growth through the liquidisable wealth beside it's direct effect. An increase in the real interest rate indicates higher discounting on future housing service flows, hence lower current value of housing asset. Therefore, the indirect effect of real interest rate is negative.

Explaining the variation in the consumption growth under standard preferences indicates the EIS parameter to be around 0.8-0.9. Under temptation preferences, real interest rate has a strong negative indirect effect through the liquidisable wealth. Consequently, explaining the same variation of consumption growth with the same variation of the real interest rate is only possible if the EIS is higher than under standard preferences, in order to compensate for the negative indirect effect. This is why in column 3 and 4 of Table 2 we find the estimated EIS parameter to be around 1.9.

3.4.2 Teptation Parameter

The other parameter of interest is the temptation parameter, which is naturally calculated only for the models with temptation preferences. Testing the empirical existence of temptation is equivalent to test the null hypothesis that the parameter of absolute temptation is zero, $\lambda = 0$. It follows from equation (23) that testing the hypothesis that $\lambda = 0$ is the same as to test that $\theta_3 = 0$. Both of the temptation models indicate rejection of the null hypothesis that $\theta_3 = 0$, providing support for the empirical presence of temptation.

As both of the degrees of absolute and relative temptation parameters are nonlinear functions of θ_3, I again apply the Delta-Method to approximate them and present the corresponding results in Table 2. The estimate for the degree of relative temptation is around 0.168 with reasonable precision and there is no significant difference in the estimates between the two models with temptation preferences, i.e. columns 3 and 4 of Table 2.

The value of 0.16 for the temptation parameter suggests that temptation plays a very important role in households' decision. If the benefit from consuming an additional unit of consumption in utility terms is one, then the cost of resisting the extra temptation caused by an additional unit in the most tempting consumption alternative is 0.16 in utility terms.

4 Numerical solution

So far what I have done is to identify some of the key model parameters. In order to understand the main mechanism of the structural model I want to simulate this model. Simulation needs the optimal policy functions, which I can not derive analytically, therefore I need to apply numerical techniques. The price I have to pay for the simulation is that I need to specify everything in the model. I can not be for example agnostic about the house price or the income process anymore. Keeping this in mind, I try to be as realistic in parameter setting as I possibly can.

I start this section with the calibration of the rest of the parameters. Some of them are estimated from different data sources, while other parameter values are adapted from elsewhere in the literature. After setting the parameter values, I use backward induction technique in order to approximate optimal policy functions, which are the combinations of control variables that yields the highest utility given the combination of states. Having calculated the optimal policy functions, I draw realisations for the idiosyncratic income shocks for each household individually, and for the aggregate house price shock. Then I simulate the entire life cycle of housing decision for large number of households.

4.1 Model Calibration

Now I discuss how I determine the parameters required for the model solution and simulation. I estimate some of the parameters from different data sources, while I use values from the existing literature for other parameters.

Income process. To obtain the age-specific component of the life-cycle income profiles (G), I fit a second-order age polynomial on the logarithm of cohort income data gathered from CEX.

$$\overline{\ln(y_t)}^g = \beta_0 + \beta_1 age_{g,t} + \beta_2 \frac{age_{g,t}^2}{10} + u_{g,t}^y \tag{31}$$

where g stands for group/cohort averages. The age of the cohort, age_g is calculated by taking average age over those household heads who belong to the same group. The regression results are presented in Table 3, while the corresponding deterministic life-cycle income profile is in Figure 1.The replacement rate (a) is calculated on the same

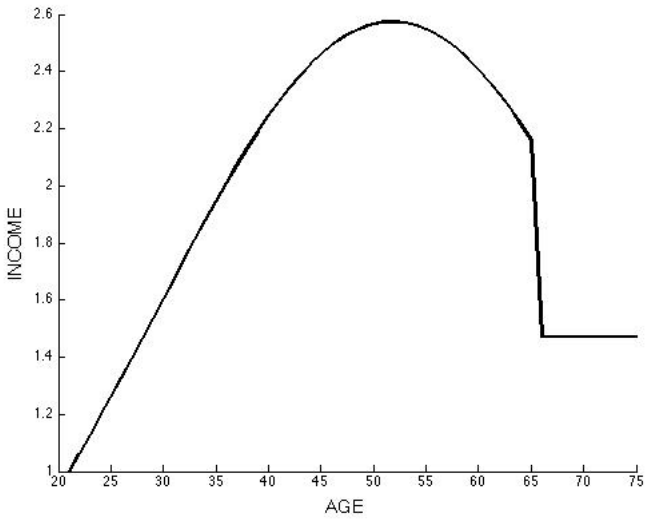


Figure 1: DETERMINISTIC INCOME OVER THE LIFE-CYCLE

dataset as the ratio of average labor income for retirees to the average of labor income in the last working year prior to retirement.[12] I do not estimate the income shock parameters (σ_n, σ_z), but use the estimates of Carroll and Samwick (1997).

	$\log y$	Standard dev.
Age	0.101***	(0.005)
$Age^2/10$	-0.010***	(0.001)
$Constant$	8.574***	(0.083)
a	0.719	
Observations	715	
R-squared	0.562	

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

Table 3: INCOME PROCESS

House price process. Estimation of the parameters of the house price process is based on the Case-Shiller real home price index series for the U.S., for years 1994-2011. I estimate an AR(1) process with linear trend for the logarithm of real Case-Shiller index.

$$\log Q_{t+1} = d_0 + d_1 t + \rho_h \log Q_t + \log \varepsilon_t$$

[12] In the U.S. the early retirement age is 62, while the normal retirement age is 67. I consider 8-year intervals for labor income comparison. I set retirees' age band for 62-69, while the last working period to age band of 54-61.

The result of the estimation is in Table 4. The persistence parameter, ρ_h of the log house price is estimated to be very close to 1 and the unit root tests do not reject the null hypothesis, that this parameter is actually 1. It implies that the log house price process can be approximated by a random walk. The estimated standard deviation of the house price shock, σ_ε equals to 0.024.

	$\log Q$	Standard dev.
t	-0.0006***	(0.0002)
$\log Q(-1)$	1.026***	(0.021)
Constant	-0.106	(0.096)
σ_ε	0.0237	
Observations	67	
R-squared	0.986	

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

Table 4: HOUSE PRICE PROCESS

Housing service. I estimate the annual housing service flow over housing stock (b) based on statistics of Bureau of Economic Analysis (BEA). I use housing gross value added at current dollars to approximate the housing service flow. Gross housing value added can be found in Table 7.4.5, "Housing Sector Output, Gross Value Added and Net Value Added" in National Income and Product Accounts (NIPA) of the BEA. I use residential fixed assets at current dollars to approximate housing stock. Residential fixed assets can be found in Table 1.1, "Current-Cost Net Stock of Fixed Assets and Consumer Durable Goods" of the Fixed Asset Tables of the BEA. The average of gross housing value added over residential fixed assets over the period 1994-2011 is 8.6%.

Housing share in composite good. I calculate the share of housing services in total consumption from aggregate data the same way as I did calculate housing service flow from the BEA data. I divide housing services with total consumption net of health and educational expenditures. I take all the data from Table 2.4.5., "Personal Consumption Expenditures by Type of Product" of the Bureau of Economic Analysis. The average share over the period of 1994-2011 is 0.18, thus the share of non-housing consumption is 0.82.

The benchmark model parameters are collected in Table 5.

Parameter		***Value***	***Source***
T_start	*Age of entering model*	20	
T_ret	*Age of retirement*	65	
β	*Discount factor*	0.95	
ρ	*Risk aversion parameter*	0.36	Own calculations, CEX
λ	*Absolute tenptation parameter*	0.2	Own calculations, CEX
Constant	*Age-specific income, constant*	8.574	Own calculations, CEX
Age	*Age-specific income, linear trend*	0.101	Own calculations, CEX
$Age^2/10$	*Age-specific income, quadratic trend*	-0.010	Own calculations, CEX
a	*Replacement rate*	0.68	Own calculations, CEX
σ_n	*Std.dev.permanent income shock*	0.147	Carroll and Samwick (1997)
σ_z	*Std.dev.transitory income shock*	0.21	Carroll and Samwick (1997)
σ_ε	*Std.dev.house price shock*	0.024	Own calculation, Case-Shiller
ρ_h	*Persistence parameter for house price*	1	Own calculation, Case-Shiller
R^X	*Liquid asset return*	1.02	Gourinchas and Parker (2002)
R^M	*Mortgage rate*	1.03	
α	*Weight of durables in composite good*	0.82	Own calculations, BEA
b	*Housing service technology*	0.086	Own calculations, BEA
δ	*Liquidity parameter*	0.5	
ψ	*Down-payment requirement*	0.2	

Table 5: ANNUAL PARAMETERS FOR THE BENCHMARK MODEL

4.2 Backward Induction

Given the finite nature of the problem, a solution exists and can be obtained by approximating optimal policy functions with backward induction technique.[13]. I use backward induction over the normalised value function (Carroll (1997)) to obtain the optimal policy functions. Value functions are approximated by discretising the normalised state variables, (x_t, h_t, m_t), Q_t and normalised control variables, (c_t, i_t, υ_t) with logarithmically spaced grids and the income shocks and house price shocks $(Z_t, N_t, \varepsilon_t)$ with Gauss-Hermite nodes. I hold all the grids constant, though every time the household reaches the upper end of the grid later in the simulation, I increase the maximum values for all grids. In each period I calculate the utility associated with given states of cash-on-hand, housing stock, mortgage stock, house price and different choices of consumption, housing investment and net new mortgage. The choices which are not possible according to constraints are given a very high negative utility in order not to be chosen.

In the last period (because of the absence of bequest motive and uncertain end of life assumption) households consume all their available liquidsiable wealth after paying back outstanding mortgage. Consequently, they make their optimal decision based on the instantaneous utility only. Therefore the utility function coincides with the value

[13]Judd (1998)

function in the last period. Knowing last period's policy functions, I am able to compute the value function for all possible combination of states.

In the next to last period, the value function is the sum of the utility function and the expected discounted continuation value that corresponds to the chosen control variables and current states.

$$V_t(\omega_t) = \max_{\{c_t, i_t, v_t\}} U(c_t, \tilde{c}_t, s_t) + \beta \mathbb{E}_t V_{t+1}(\omega_{t+1}) \tag{32}$$

Expectation refers to the uncertain income and house price shocks, and again expectation are evaluated by using the Gauss-Hermite approximation. Since Z_{t+1}, N_{t+1} and ε_{t+1} are log-normally distributed random variables in each period, we are able to use a three-dimensional Gauss-Hermite quadrature to approximate the expectations as follows

$$\begin{aligned} \mathbb{E}_t V_{t+1}(\omega_{t+1}) &= \int V_{t+1}\Big(\omega_{t+1}(Z, N, \varepsilon)\Big)\, \mathrm{d}F(Z)\mathrm{d}F(N)\mathrm{d}F(\varepsilon) \\ &= \int_{-\infty}^{\infty} \frac{1}{\pi} V_{t+1}\Big(\omega_{t+1}(\sqrt{2}\sigma_Z Z, \sqrt{2}\sigma_N N, \sqrt{2}\sigma_\varepsilon \varepsilon)\Big) e^{-(Z^2+N^2+\varepsilon^2)} \\ &\approx \sum_{i \bigotimes j \bigotimes k} \frac{1}{\pi} w_i^{GH} w_j^{GH} w_k^{GH} V_{t+1}\Big(\omega_{t+1}(\sqrt{2}\sigma_Z Z_i^{GH}, \sqrt{2}\sigma_N N_j^{GH}, \sqrt{2}\sigma_\varepsilon \varepsilon_k^{GH})\Big) \end{aligned} \tag{33}$$

where Z_i^{GH}s, N_j^{GH}s and ε_k^{GH}s are the Gauss-Hermite nodes and w_i^{GH}, w_j^{GH} and w_k^{GH} are the corresponding weights.

First, continuation values are calculated for all combinations of current states, controls and discretised Gauss-Hermite shocks. For a particular combination of states, controls and shocks I use the laws of motion for for cash-on-hand, housing asset, mortgage stock and house price to get next period values for states. These values of state variables may not be on the state space grid, for which I calculated the values in the last period, therefore I use interpolation to evaluate value function between grid points. The interpolation method is the so-called shape-preserving, piecewise cubic Hermite interpolating polynomial.

Second, the expected continuation values are calculated according to equation (33), where I tabulate the weights and nodes with a quadrature of order 5. Knowing the expected continuation value for all points on the grid-space, the optimisation can be easily made over all control variables. The optimal policy for each combination of states refers to the combination of control variables that gives the highest utility in a given period. Having the value function calculated for the next to last period for all combinations of states, I can iterate backwards and solve for all the previous periods in the same way. As a result, I get the optimal policies for each combination of states and for each time period over the life-cycle for consumption, housing investment and the net new mortgage.

4.3 Simulation

Having optimal policy functions at hand, I simulate the behaviour of households over the life cycle. For each simulation I draw realisations for the two individual shocks, the permanent income shock and the transitory income shock and realisation for house price shocks. As I disregard from any kind of bequest motive, households start their life with zero wealth, but they get labour income. Knowing initial state variables, and using the policy functions derived, I calculate the optimal choice of consumption, housing investment and net new mortgage. Again, in case states are not on the grid, I use linear interpolation to evaluate policy function between grid points. With state variables, control variables and shocks at hand, next period states can be calculated using laws of motion. This forward iteration process is then repeated till the end of the life cycle. Altogether I run 100 simulations, with 1000 households each.

4.4 Results

In this section I present the simulation results for the temptation model with the benchmark parameters shown in Table 5. The set of graphs in Figure 2-5 shows the average simulated life cycle profiles of selected model variables up to age 75.

The composite consumption is hump-shaped, it peaks at around age 55 and has a sizeable drop at retirement.

There is a massive housing asset accumulation up until retirement, when housing asset starts to decrease in order to support consumption after the significant permanent income drop. As households derive utility from housing asset till the very last period of their life, housing asset is kept until death. But also for the same reason and the feature of housing asset being illiquid,

Cash-on-hand and labor income are both hump-shaped and only differ significantly between age 40 and 60. It indicates that the accumulation in liquid asset, compared to illiquid housing asset is smaller by an order of magnitude. The relatively low demand of liquid asset can be explained by feature of housing asset being not fully illiquid. By assumption, an exougenous δ fraction of housing asset can be liquidated. That part of the hosing asset behaves as if it was another liquid asset, which produces housing service and in the same time also affects the marginal utility of the nondurable consumption.

Mortgage stock tracks housing asset profile and on average around 40-45% of housing asset is financed by mortgage loan. Mortgage market let credit constrained households take out mortgage and bring some of their lifetime consumption forward in order to smooth life-cycle consumption profile.

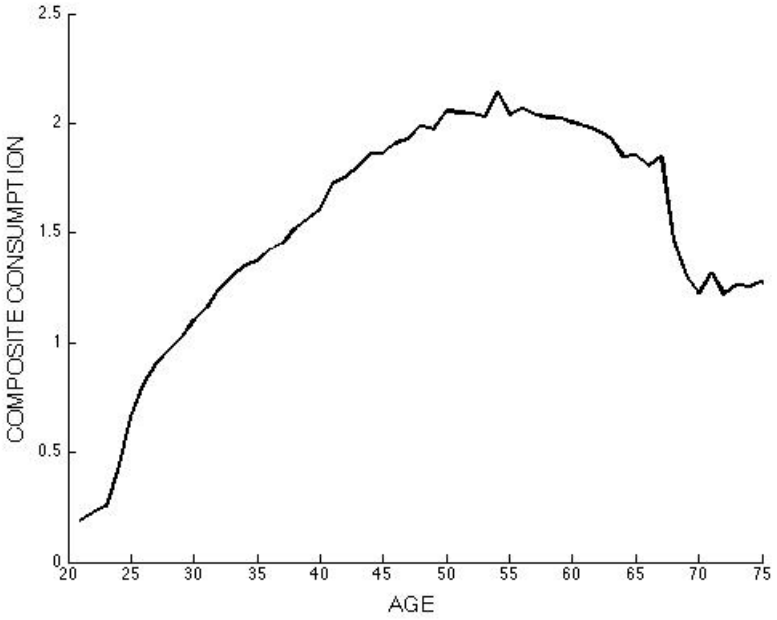


Figure 2: SIMULATED COMPOSITE CONSUMPTION

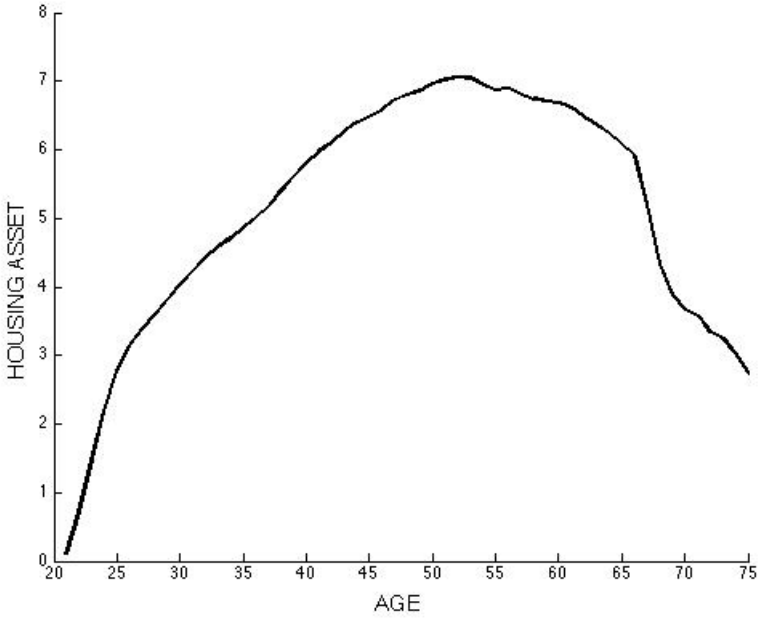


Figure 3: SIMULATED HOUSIHG ASSET

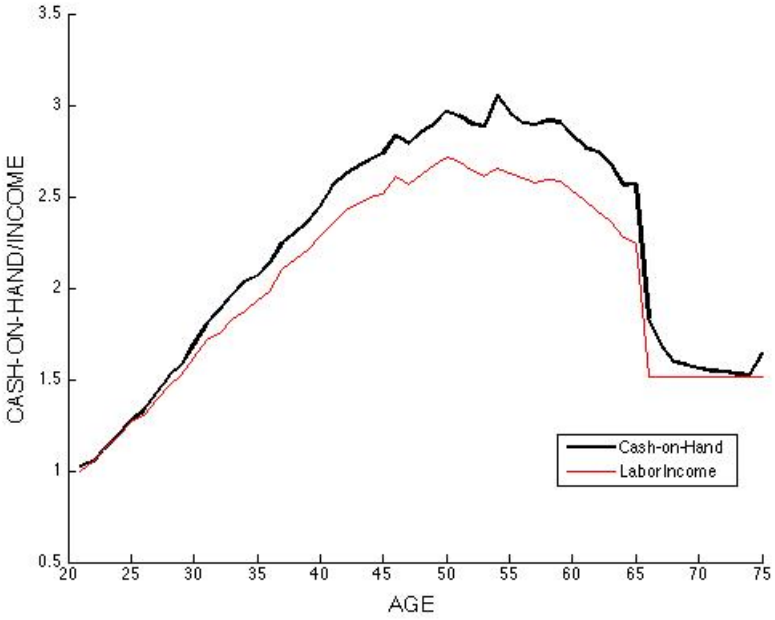


Figure 4: SIMULATED CASH-ON-HAND AND LABOR INCOME

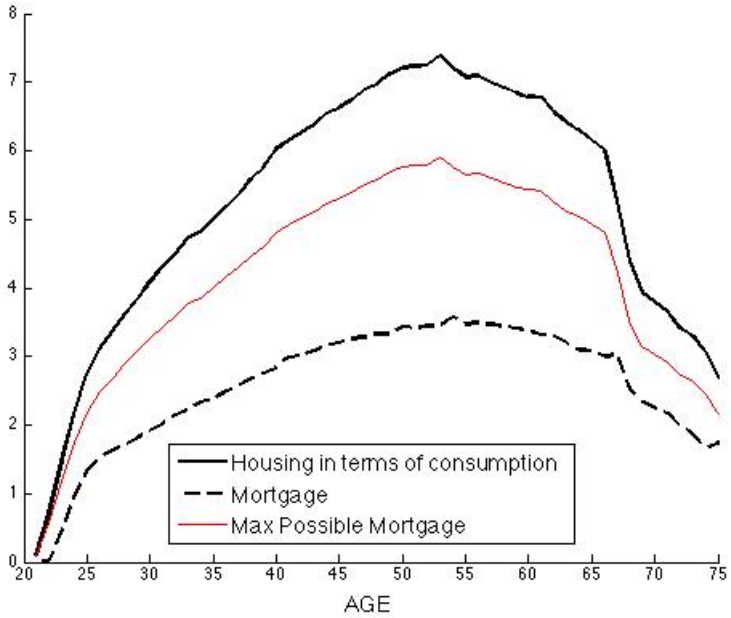


Figure 5: SIMULATED HOUSING AND MORTGAGE

4.5 The role of the liquidity parameter

One crucial parameter of the model is the liquidity parameter of the housing asset, δ, which effects the system through the budget constraint. Notice that under temptation preferences this parameter has an effect on the housing demand through two channels: the investment and the commitment channel. In case the liquidity parameter ceteris paribus increases, i.e. housing asset gets more liquid, on the one hand housing asset becomes more attractive to invest in (investment channel), but on the other hand it becomes less attractive to hold as a commitment device (commitment channel). The higher the liquidity parameter is, the higher fraction of housing asset can be liquidated and spent on nondurable consumption immediately. Consequently the less efficiently tempted households can use housing asset as commitment device. These two channels are working into opposite directions and I am not able to determine their strength separately. What I can do in the next exercise is to quantify the lower bound for the commitment channel of housing demand by changing the liquidity parameter ceteris paribus.

In Figure 6 I plot the result of the liquidity parameter change on the life-cycle paths of housing demand. The straight black line is the benchmark case with $\delta = 0.5$, the dashed line corresponds to a lower liquidity level $\delta = 0.3$, while the dotted line represents the case of housing asset being fully liquid with $\delta = 1$.

It is clear from the graph that a ceteris paribus increase in the liquidity of the housing asset leads to a decrease in demand for housing asset over the life-cycle. This shows that the commitment channel of housing demand is much stronger than the the investment channel. Housing asset does serve less as commitment device and housing demand decreases by around 50 percent at the peak of the life-cycle.

A ceteris paribus decrease in the liquidity of the housing asset on the other hand leads to an increase in demand for housing asset. Again, this is a sign that commitment channel can not be compensated by the investment channel of the housing asset demand. Housing asset serves better as commitment device, hence housing demand increases by around 15 percent at the peak of the life-cycle.

As these observed effects are the results of the two channels together, they only represents a lower bound for the strength of the commitment channel on the housing asset demand. It seems that housing asset as commitment device is quantitatively very important for tempted households who intend to decrease their cost of self-control by holding their savings in illiquid asset. Figure 6 shows that a significant fraction of the housing asset demand can be explained by the illiquidity of housing, hence by the commitment channel.

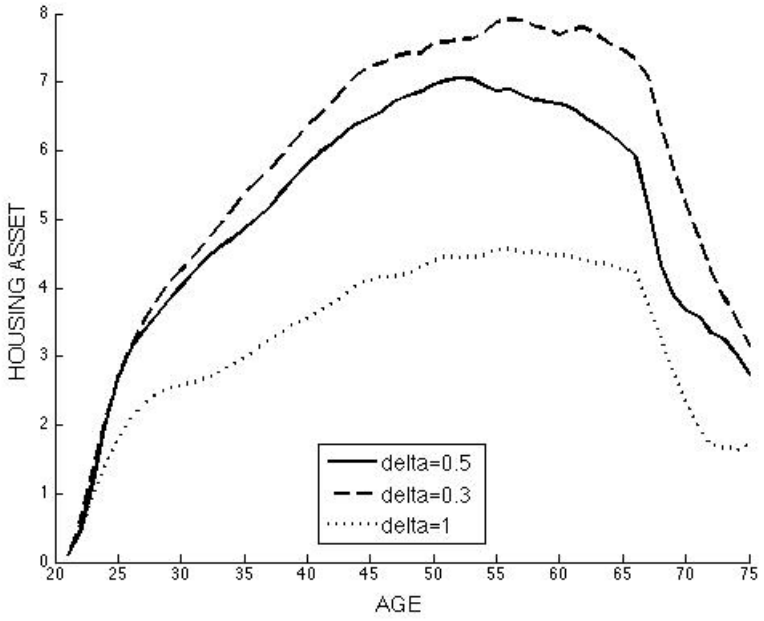


Figure 6: THE EFFECT OF THE LIQUIDITY PARAMETER

4.6 The role of the temptation parameter

The other crucial parameter in the model is the temptation parameter, λ, which effects the system through the utility function. This parameter drives the importance of the tempting alternative. A decrease in parameter λ leads to a drop in housing demand as households gets more tempted, consequently the cost of self-control increases and households resist temptation less. In this section I quantify the importance of temptation by changing liquidity parameter ceteris paribus.

In Figure 7 I plot the result of the temptation parameter change on the life-cycle paths of housing demand. The straight black line is the benchmark case with $\lambda = 0.2$, the dashed line corresponds to a lower temptation parameter $\lambda = 0.1$, while the dotted line represents the case of higher temptation parameter $\lambda = 0.3$.

The graph shows that a ceteris paribus increase in the temptation parameter leads to a decrease in demand for housing asset over the life-cycle. This is because households with higher temptation parameter are more tempted, hence resist temptation less and also are able to save less. Housing demand decreases by around 30 percent when temptation parameter changes from $\lambda = 0.2$ to $\lambda = 0.3$.

Decreasing the temptation parameter ceteris paribus from $\lambda = 0.2$ to $\lambda = 0.1$ on the other hand leads to an increase in demand for housing. Given lower temptation parameter, households are less tempted and resist temptation more, hence they are also able to save more. Housing demand increases by around 35 percent at the peak of the life-cycle.

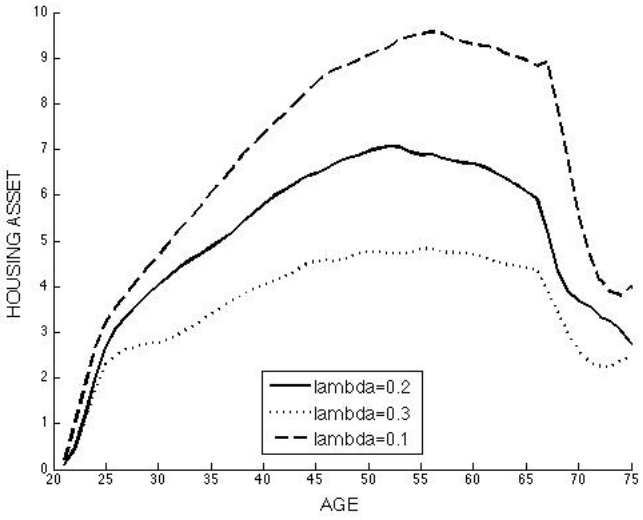


Figure 7: THE EFFECT OF THE TEMPTATION PARAMETER

So the role of temptation parameter in the context of housing demand has also great quantitatively importance. Temptation parameter affects the cost of resisting temptation households face, which makes them to save less. This effect is expressed in lower demand for housing asset.

5 Conclusion

In this paper, I show evidence that preferences by Gul-Pesendorfer, which allow for temptation and self-control can not be rejected empirically. The estimation on household-level CEX data indicates that the temptation parameter is significantly different from zero.

I present an simple, finite-horizon consumption-savings model that allows for temptation and self-control in preferences. Temptation and corresponding cost of self-control may generate demand for commitment devices. As I have shown in the model simulation, illiquid housing asset indeed plays an important role as commitment device, beside being consumption, investment and collateral device. This is because holding savings in illiquid housing asset decreases temptation and consequently the cost of self-control. Quantitatively, in case housing asset is illiquid (with parameter $\delta = 05$, it's demand is 50 percent higher then in case housing asset is fully liquid.

6 Appendix

6.1 The problem

$$\begin{aligned} V_t(\Omega_t) &= \max_{\{C_t, I_t, \Upsilon_t\}} U(C_t, \tilde{C}_t, S_t) + \beta E_t V_{t+1}(\Omega_{t+1}) \\ \Omega_t &= (X_t, H_t, M_t, Q_t, Y_t^P) \end{aligned}$$

subject to a set of constraints

$$\begin{aligned} X_{t+1} &= R^X(X_t - C_t - Q_t I_t + \vartheta_t - \xi_t(M_t)) + Y_{t+1} \\ H_{t+1} &= H_t + I_t \\ M_{t+1} &= R^M M_t + \vartheta_t - \xi_t(M_t) \\ S_t &= bH_t \\ -\delta H_t &\leq I_t \\ \Upsilon_t &= \vartheta_t - \xi_t(M_t) \\ r^M M_t &\leq \xi_t(M_t) \leq R^M M_t \\ \vartheta_t &\leq (1-\psi)Q_t H_t - R^M M_t \qquad \text{if} \quad (1-\psi)Q_t H_t > R^M M_t \\ \vartheta_t &= 0 \qquad \text{if} \quad (1-\psi)Q_t H_t \leq R^M M_t \\ \tilde{C}_t &= \arg\max_{C_t}(\nu(C_t, S_t)) = X_t + \delta Q_t H_t \end{aligned}$$

6.2 The Gul-Pesendorfer framework

The main difference between standard assumptions of dynamic decision theory and Gul and Pesendorfer's framework can be summarized as follows. According to the standard theory, preferences are defined over objects. Adding objects to a set, cannot make the set worse. While in Gul-Pesendorfer's temptation model, preferences are defined over sets of objects. Adding objects to a the set can make the set itself worse through the temptation of the new object added to the set. Gul and Pesendorfer derive temptation preferences with self control based on four axioms. Three of them are standard axioms of set theory.

AXIOM 1 (Preference Relation): $\succeq$ is a complete and transitive binary relation

AXIOM 2 (Strong Continuity): The sets $\{B : B \succeq A\}$ and $\{B : A \succeq B\}$ are closed

AXIOM 3 (Independence): $A \succ B$ and $\alpha \in (0,1)$ implies $\alpha A + (1-\alpha)C \succ \alpha B + (1-\alpha)C$

AXIOM 4 (Set Betwenness): $A \succeq B$ implies $A \succeq A \cup B \succeq B$

The first three axioms are standard, but the last axiom, *Set Betweenness* is the one let the people be tempted by the additional alternative in the set and exercise self control too. The preference between set A and set $A \cup B$ shows that an alternative (in set B) which is not chosen may affect the utility of the decision maker because it causes temptation. The assumptions are that temptation is utility decreasing, all the alternatives can be ranked according to how tempting they are and only the most tempting alternative available affects the decision-maker's utility. While the preference between $A \cup B$ and B indicates that the people may exercise self control.

The binary relation $\succeq$ satisfies Axioms $1-4$ if and only of there are continuous linear functions U, u, v such that

$$U(A) := \max_{x \in A}[u(x) - (max_{y \in A} v(y) - v(x))]$$

for all A and U represents $\succeq$. Where u represents people's long run/commitment utility over alternatives, v represents people's temptation utility over alternatives, hence we can interpret $max_{y \in A} v(y) - v(x)$ as the utility cost of self control. In other words, we can think about alternatives as they have two types of ranking, the commitment and the temptation ranking. When we decide on which alternative we would like to consume, we take a look at both ranking and maximize the possible utilities. After the decision, we enjoy the commitment and temptation utility of the alternative we did choose, but we have the loss of the temptation utility of the best alternative which we could have chosen as well.

6.3 Standardization

At terminal age $t = T$ the value function becomes

$$V_T(\Omega_T) = \frac{(C_T^\alpha S_T^{1-\alpha})^{1-\rho}}{1-\rho} - \lambda \frac{(\tilde{C}_T^\alpha S_T^{1-\alpha})^{1-\rho}}{1-\rho} + \lambda \frac{(C_T^\alpha S_T^{1-\alpha})^{1-\rho}}{1-\rho}$$

With standardized variables, using notation $\omega_T = (x_T, h_T, m_T, Q_T)$, the value function is

$$\begin{aligned} V_T(\omega_T) &= U(c_T, s_T, \tilde{c}_T) \\ &= U\left(\frac{C_T}{Y_T^P}, \frac{S_T}{Y_T^P}, \frac{\tilde{C}_T}{Y_T^P}\right) \\ &= (1+\lambda)\frac{((\frac{C_T}{Y_T^P})^\alpha(\frac{S_T}{Y_T^P})^{1-\alpha})^{1-\rho}}{1-\rho} - \lambda\frac{\left(\tilde{C}_T^\alpha(\frac{X_T}{Y_T^P}, \frac{H_T}{Y_T^P})(\frac{S_T}{YP_T})^{1-\alpha}\right)^{1-\rho}}{1-\rho} \end{aligned}$$

First we should get the relationship between $\tilde{C}_T\left(\frac{X_T}{Y_T^P}, \frac{H_T}{Y_T^P}\right)$ and $\tilde{C}_T\left(X_T, H_T\right)$

$$\begin{aligned} \tilde{C}_T\left(\frac{X_T}{Y_T^P}, \frac{H_T}{Y_T^P}\right) &= \frac{X_T}{Y_T^P} + \delta Q_T \frac{H_T}{Y_T^P} \\ &= \frac{1}{Y_T^P}(X_T + \delta Q_T H_T) \end{aligned}$$

So

$$\tilde{c}_T = \tilde{C}_T\left(\frac{X_T}{Y_T^P}, \frac{H_T}{Y_T^P}\right) = \frac{\tilde{C}_T\left(X_T, H_T\right)}{Y_T^P}$$

Hence the value function can be rewritten as

$$\begin{aligned} V_T(\omega_T) &= (1+\lambda)\frac{((\frac{C_T}{Y_T^P})^\alpha(\frac{S_T}{Y_T^P})^{1-\alpha})^{1-\rho}}{1-\rho} - \lambda\frac{((\frac{\tilde{C}_T}{Y_T^P})^\alpha(\frac{S_T}{Y_T^P})^{1-\alpha})^{1-\rho}}{1-\rho} \\ &= \frac{1}{(Y_T^P)^{1-\rho}}\left\{(1+\lambda)\frac{(C_T^\alpha S_T^{1-\alpha})^{1-\rho}}{1-\rho} - \lambda\frac{(\tilde{C}_T^\alpha S_T^{1-\alpha})^{1-\rho}}{1-\rho}\right\} \end{aligned}$$

Hence we get

$$V_T(\Omega_T) = (Y_T^P)^{1-\rho} V_T(\omega_T)$$

The value function at age $t = T-1$ is

$$V_{T-1}(\Omega_{T-1}) = (Y_{T-1}^P)^{1-\rho} \max_{c_{T-1}, i_{T-1}, \Upsilon_{T-1}} \left\{U(c_{T-1}, s_{T-1}, \tilde{c}_{T-1}) + E_{T-1}\left[\beta\left(\frac{Y_T^P}{Y_{T-1}^P}\right)^{1-\rho} V_T(\omega_T)\right]\right\}$$

Using that

$$\max_{c_{T-1},i_{T-1},\Upsilon_{T-1}} \left\{ U(c_{T-1}, s_{T-1}, \tilde{c}_{T-1}) + E_{T-1}\left[\beta \left(\frac{Y_T^P}{Y_{T-1}^P}\right)^{1-\rho} V_T(\omega_T)\right]\right\} = \max_{c_{T-1},i_{T-1},\Upsilon_{T-1}} \{U(c_{T-1}, s_{T-1}, \tilde{c}_{T-1}) + E_{T-1}\beta V_T(\omega_T)\}$$

We get, similarly to the previous result

$$V_{T-1}(\Omega_{T-1}) = (Y_{T-1}^P)^{1-\rho} V_{T-1}(\omega_{T-1})$$

It can be shown that this relationship holds at a generic time t, hence the value function and the standardized value function at any point in time only differ by a scale factor. It is equivalent to maximize either function.

6.4 Solution

Our stationary value function for the problem takes the following form

$$V_t(\omega_t) = \max_{c_t,i_t,\Upsilon_t} \left\{ U(c_t, s_t, \tilde{c}_t) + E_t[\beta_{t+1}^* V_{t+1}(\omega_{t+1})] \right\}$$

with

$$\beta_{t+1}^* = \beta \left(\frac{Y_{t+1}^P}{Y_t^P}\right)^{1-\rho}$$

subject to the standardized budget constraints

$$x_{t+1} \leq R^X(x_t - c_t - Q_t i_t + \upsilon_t)\frac{Y_t^P}{Y_{t+1}^P} + \frac{Y_{t+1}}{Y_{t+1}^P}$$

$$h_{t+1} \leq (h_t + i_t)\frac{Y_t^P}{Y_{t+1}^P}$$

$$m_{t+1} \leq (R^M m_t + \upsilon_t)\frac{Y_t^P}{Y_{t+1}^P}$$

From equations (12)-(14), we know that

$$\frac{Y_t^P}{Y_{t+1}^P} = \begin{cases} \frac{1}{G_{t+1}N_{t+1}} & \text{if } t \leq T_{ret} \\ 1 & \text{if } t > T_{ret} \end{cases}$$

and

$$\frac{Y_{t+1}}{Y_{t+1}^P} = \begin{cases} Z_{t+1} & \text{if } t \leq T_{ret} \\ a & \text{if } t > T_{ret} \end{cases}$$

The first order condition of the derived value function $V_t(\omega_t)$ with respect to c_t:

$$\frac{\partial U_t(c_t, s_t, \tilde{c})}{\partial c_t} = E_t \left[\beta_{t+1}^* \frac{Y_t^P}{Y_{t+1}^P} R^X \frac{\partial V_{t+1}(\omega_{t+1})}{\partial x_{t+1}} \right]$$

Lets define from now on $\beta_{t+1} = \beta_{t+1}^* \frac{Y_t^P}{Y_{t+1}^P} = \beta \left(\frac{Y_{t+1}^P}{YP_t} \right)^{-\rho}$.

$$\frac{\partial U_t(c_t, s_t, \tilde{c}_t)}{\partial c_t} = E_t \left[\beta_{t+1} R^X \frac{\partial V_{t+1}(\omega_{t+1})}{\partial x_{t+1}} \right] \tag{34}$$

The first order condition with respect to i_t:

$$E_t \left[R^X \frac{\partial V_{t+1}(\omega_{t+1})}{\partial x_{t+1}} \right] = E_t \left[\frac{1}{Q_t} \frac{\partial V_{t+1}(\omega_{t+1})}{\partial h_{t+1}} \right] \tag{35}$$

The first order condition with respect to Υ_t:

$$E_t \left[R^X \frac{\partial V_{t+1}(\omega_{t+1})}{\partial x_{t+1}} \right] = -E_t \left[\frac{\partial V_{t+1}(\omega_{t+1})}{\partial m_{t+1}} \right] \tag{36}$$

The envelope condition with respect to x_t is

$$\frac{\partial V_t(\omega_t)}{\partial x_t} = \frac{\partial U_t(c_t, s_t, \tilde{c}_t)}{\partial \tilde{c}_t} + E_t \left[\beta_{t+1} R^X \frac{\partial V_{t+1}(\omega_{t+1})}{\partial x_{t+1}} \right] \tag{37}$$

The envelope condition with respect to h_t is

$$\frac{\partial V_t(\omega_t)}{\partial h_t} = b \frac{\partial U_t(c_t, s_t, \tilde{c}_t)}{\partial s_t} + \delta Q_t \frac{\partial U_t(c_t, s_t, \tilde{c}_t)}{\partial \tilde{c}_t} + E_t \left[\beta_{t+1} \frac{\partial V_{t+1}(\omega_{t+1})}{\partial h_{t+1}} \right] \tag{38}$$

The envelope condition with respect to m_t is

$$\frac{\partial V_t(\omega_t)}{\partial m_t} = E_t \left[\beta_{t+1} R^M \frac{\partial V_{t+1}(\omega_{t+1})}{\partial m_{t+1}} \right] \tag{39}$$

Using equation (34) and (37) it turns out that

$$\frac{\partial V_t(\omega_t)}{\partial x_t} = \frac{\partial U_t(c_t, s_t, \tilde{c}_t)}{\partial \tilde{c}_t} + \frac{\partial U_t(c_t, s_t, \tilde{c}_t)}{\partial c_t} \tag{40}$$

Using equation (34)-(36) and (38)

$$\frac{\partial V_t(\omega_t)}{\partial h_t} = b\frac{\partial U_t(c_t, s_t, \tilde{c}_t)}{\partial s_t} + \delta Q_t \frac{\partial U_t(c_t, s_t, \tilde{c}_t)}{\partial \tilde{c}_t} + Q_t \frac{\partial U_t(c_t, s_t, \tilde{c}_t)}{\partial c_t} \tag{41}$$

Using equation (34),(35) and (39)

$$\frac{\partial V_t(\omega_t)}{\partial m_t} = -R^M \frac{\partial U_t(c_t, s_t, \tilde{c}_t)}{\partial c_t} \tag{42}$$

Hence we can rewrite the first order conditions using (40)-(42)

$$\begin{aligned}
\frac{\partial U_t}{\partial c_t} &= E_t\left[\beta_{t+1} R^X \left(\frac{\partial U_{t+1}}{\partial \tilde{c}_{t+1}} + \frac{\partial U_{t+1}}{\partial c_{t+1}}\right)\right] \\
\frac{\partial U_t}{\partial c_t} &= E_t\left[\beta_{t+1} \frac{1}{Q_t}\left(b\frac{\partial U_{t+1}}{\partial s_{t+1}} + \delta Q_t \frac{\partial U_{t+1}}{\partial \tilde{c}_{t+1}} + Q_t \frac{\partial U_{t+1}}{\partial c_{t+1}}\right)\right] \\
\frac{\partial U_t}{\partial c_t} &= E_t\left[\beta_{t+1} R^M \frac{\partial U_{t+1}}{\partial c_{t+1}}\right]
\end{aligned}$$

Now using the utility function defined by equations (16) and (18):

$$U_t(c_t, s_t, \tilde{c}_t) = \frac{(c_t^\alpha s_t^{1-\alpha})^{1-\rho}}{1-\rho} - \left[\lambda \frac{(\tilde{c}_t^\alpha s_t^{1-\alpha})^{1-\rho}}{1-\rho} - \lambda \frac{(c_t^\alpha s_t^{1-\alpha})^{1-\rho}}{1-\rho}\right]$$

where

$$\begin{aligned}
\tilde{c}_t &= x_t + \delta Q_t h_t \\
s_t &= b h_t
\end{aligned}$$

we can derive Euler equations for the different assets.
The ***euler equation for cash-on-hand***

$$(1+\lambda)\alpha \frac{(c_t^\alpha s_t^{1-\alpha})^{1-\rho}}{c_t} = E_t\left[\beta_{t+1} R^X \left((1+\lambda)\alpha \frac{(c_{t+1}^\alpha s_{t+1}^{1-\alpha})^{1-\rho}}{c_{t+1}} - \lambda\alpha \frac{(\tilde{c}_{t+1}^\alpha s_{t+1}^{1-\alpha})^{1-\rho}}{\tilde{c}_{t+1}}\right)\right]$$

The ***euler equation for housing asset***

$$(1+\lambda)\alpha\frac{(c_t^\alpha s_t^{1-\alpha})^{1-\rho}}{c_t} = E_t\Bigg[\beta_{t+1}\Bigg((1+\lambda)\alpha\frac{(c_{t+1}^\alpha s_{t+1}^{1-\alpha})^{1-\rho}}{c_{t+1}} + \frac{(1-\alpha)(1+\lambda)b}{Q_t}\frac{(c_{t+1}^\alpha s_{t+1}^{1-\alpha})^{1-\rho}}{s_{t+1}} \\ -\delta\lambda\alpha\frac{(\tilde{c}_{t+1}^\alpha s_{t+1}^{1-\alpha})^{1-\rho}}{\tilde{c}_{t+1}} - \frac{(1-\alpha)\lambda b}{Q_t}\frac{(\tilde{c}_{t+1}^\alpha s_{t+1}^{1-\alpha})^{1-\rho}}{s_{t+1}}\Bigg)\Bigg]$$

And the ***euler equation for mortgage***

$$(1+\lambda)\alpha\frac{(c_t^\alpha s_t^{1-\alpha})^{1-\rho}}{c_t} = E_t\left[\beta_{t+1}R^M\left((1+\lambda)\alpha\frac{(c_{t+1}^\alpha s_{t+1}^{1-\alpha})^{1-\rho}}{c_{t+1}}\right)\right]$$

The Euler equation for the liquid asset shows that the marginal cost of giving up one unit of current consumption - invested in liquid asset - must be equal to the marginal benefit of consuming the proceeds of the extra saving in the next period, minus the marginal cost of resisting the additional temptation in the next period, caused by the higher savings in liquid asset. Hence the cost of saving is higher for tempted individuals than for non-tempted ones, everything else being equal. Note that marginal benefit of consumption for next period has two terms in this case: the utility from consuming the the extra consumption and the temptation value of this extra consumption.

The Euler equation for the housing asset shows that the marginal cost of giving up one unit of current consumption - invested in housing asset - must be equal to the marginal benefit of the proceeding extra savings next period minus the marginal cost of resisting the additional temptation in the next period caused by the higher savings in housing stock.

Marginal benefit here comes from the consumption of the proceeding extra savings and its extra temptation value next period - like in the liquid asset case -, but also from the extra utility of enjoying more housing service by having the extra housing stock. The marginal cost has two sources. On the one hand extra saving in housing stock increases the next period temptation value of the best available alternative itself (as $\tilde{C}_t = \tilde{C}_t(X_t, H_t)$). On the other hand, because of higher housing stock, the temptation value of a given best alternative gets higher next period.

The first term of the marginal cost does depend on the liquidity of the housing asset (parameter δ). The temptation cost is mitigated more, the more illiquid the housing asset is. When housing asset is completely illiquid ($\delta = 0$) this cost term is eliminated.

The Euler equation for mortgage shows that the marginal benefit of using an additional unit of mortgage for consumption today must be equal to the marginal cost of the this

6.5 Log-linearizing the Euler equation for cash-on-hand

From now on, we let market return, R^X vary over time and express Euler equation (19) in the following fashion

$$1 = E_t k_{t+1} R^X_{t+1}$$

where k_{t+1} is the pricing kernel.

$$1 = E_t \left[\beta_{t+1} R^X_{t+1} \frac{c_t}{(c_t^\alpha s_t^{1-\alpha})^{1-\rho}} \left(\frac{(c_{t+1}^\alpha s_{t+1}^{1-\alpha})^{1-\rho}}{c_{t+1}} - \frac{\lambda}{1+\lambda} \frac{(\tilde{c}_{t+1}^\alpha s_{t+1}^{1-\alpha})^{1-\rho}}{\tilde{c}_{t+1}} \right) \right]$$

In our case, the pricing kernel is

$$\begin{aligned} k_{t+1} &= \beta_{t+1} \frac{c_t}{c_{t+1}} \frac{(c_{t+1}^\alpha s_{t+1}^{1-\alpha})^{1-\rho}}{(c_t^\alpha s_t^{1-\alpha})^{1-\rho}} \left[1 - \frac{\lambda}{1+\lambda} \frac{c_{t+1}}{\tilde{c}_{t+1}} \frac{(\tilde{c}_{t+1}^\alpha s_{t+1}^{1-\alpha})^{1-\rho}}{(c_{t+1}^\alpha s_{t+1}^{1-\alpha})^{1-\rho}} \right] \\ &= \beta_{t+1} \left(\frac{c_{t+1}}{c_t} \right)^{-1+\alpha(1-\rho)} \left(\frac{s_{t+1}}{s_t} \right)^{(1-\alpha)(1-\rho)} \left[1 - \frac{\lambda}{1+\lambda} \left(\frac{\tilde{c}_{t+1}}{c_{t+1}} \right)^{-1+\alpha(1-\rho)} \right] \end{aligned}$$

Let's denote now $\kappa = 1 - \alpha(1-\rho)$ to get

$$k_{t+1} = \beta_{t+1} \left(\frac{c_{t+1}}{c_t} \right)^{-\kappa} \left(\frac{s_{t+1}}{s_t} \right)^{\kappa-\rho} \left[1 - \frac{\lambda}{1+\lambda} \left(\frac{\tilde{c}_{t+1}}{c_{t+1}} \right)^{-\kappa} \right]$$

Since all the variables involved in the pricing kernel are assumed to be stationary, one can take a log-linear approximation of that around steady state. First lets take the log of the pricing kernel

$$\begin{aligned} \ln k_{t+1} &= \ln \beta_{t+1} - \kappa \ln \left(\frac{c_{t+1}}{c_t} \right) + (\kappa - \rho) \ln \left(\frac{s_{t+1}}{s_t} \right) \\ &+ \ln \left[1 - \frac{\lambda}{1+\lambda} \left(\frac{\tilde{c}_{t+1}}{c_{t+1}} \right)^{-\kappa} \right] \end{aligned}$$

Now taking the first order Taylor approximation around steady state

$$\begin{aligned} \frac{1}{k}(k_{t+1} - k) &= \frac{1}{\beta}(\beta_{t+1} - \beta) - \kappa \left[\frac{c_{t+1}}{c_t} - 1 \right] + (\kappa - \rho) \left[\frac{s_{t+1}}{s_t} - 1 \right] \\ &+ \frac{\kappa \frac{\lambda}{1+\lambda} \left(\frac{\tilde{c}}{c} \right)^{-\kappa-1}}{1 - \frac{\lambda}{1+\lambda} \left(\frac{\tilde{c}}{c} \right)^{-\kappa}} \left[\frac{\frac{\tilde{c}}{c}}{\frac{\tilde{c}}{c}} \left(\frac{\tilde{c}_{t+1}}{c_{t+1}} - \frac{\tilde{c}}{c} \right) \right] \end{aligned}$$

If we denote the percentage deviation from steady state with $\widehat{x}_t = \frac{x_t - x}{x}$, then this relationship becomes

$$\widehat{k}_{t+1} = \widehat{\beta}_{t+1} - \kappa\widehat{\left(\frac{c_{t+1}}{c_t}\right)} + (\kappa - \rho)\widehat{\left(\frac{s_{t+1}}{s_t}\right)} + \kappa\frac{\frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}}{1 - \frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}}\widehat{\left(\frac{\tilde{c}_{t+1}}{c_{t+1}}\right)}$$

where we can use

$$\phi = \frac{\frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}}{1 - \frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}} = \frac{\lambda}{\frac{1}{\frac{1}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}} - \lambda} = \frac{\lambda}{(1+\lambda)\left(\frac{\tilde{c}}{c}\right)^{\kappa} - \lambda}$$

So the log-linearized pricing kernel becomes

$$\widehat{k}_{t+1} = \widehat{\beta}_{t+1} - \kappa\widehat{\left(\frac{c_{t+1}}{c_t}\right)} + (\kappa - \rho)\widehat{\left(\frac{s_{t+1}}{s_t}\right)} + \kappa\phi\widehat{\left(\frac{\tilde{c}_{t+1}}{c_{t+1}}\right)}$$

In what follows, we use the relationship:

$$\widehat{x}_t \approx \ln x_t - \ln x$$

$$\begin{aligned}\ln k_{t+1} - \ln k &= \ln\beta_{t+1} - \ln\beta - \kappa\ln\left(\frac{c_{t+1}}{c_t}\right) + (\kappa - \rho)\ln\left(\frac{s_{t+1}}{s_t}\right) \\ &+ \kappa\phi\left[\ln\left(\frac{\tilde{c}_{t+1}}{c_{t+1}}\right) - \ln\left(\frac{\tilde{c}}{c}\right)\right] + \eta_{t+1}\end{aligned}$$

Now in the steady state

$$\ln k = \ln\beta + \ln\left[1 - \frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}\right]$$

Substituting this steady state relationship into previous equation

$$\begin{aligned}\ln k_{t+1} - \ln\left[1 - \frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}\right] &= \ln\beta_{t+1} - \kappa\ln\left(\frac{c_{t+1}}{c_t}\right) + (\kappa - \rho)\ln\left(\frac{s_{t+1}}{s_t}\right) \\ &+ \kappa\phi\left[\ln\left(\frac{\tilde{c}_{t+1}}{c_{t+1}}\right) - \ln\left(\frac{\tilde{c}}{c}\right)\right] + \eta_{t+1} \qquad (43)\end{aligned}$$

We can rewrite $-\ln\left[1 - \frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}\right]$

$$-\ln\left[1-\frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}\right]=\ln\left[1-\frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}\right]^{-1}=\ln\left(\frac{1}{1-\frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}}\right)$$

Which can be shown to be $\ln(1+\phi)$.

$$\ln(1+\phi)=\ln\left(1+\frac{\frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}}{1-\frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}}\right)=\ln\left(\frac{1}{1-\frac{\lambda}{1+\lambda}\left(\frac{\tilde{c}}{c}\right)^{-\kappa}}\right)$$

Now equation (43) can be rewritten

$$\begin{aligned}\ln k_{t+1} &= \ln\beta_{t+1}-\ln(1+\phi)-\kappa\ln\left(\frac{c_{t+1}}{c_t}\right)+(\kappa-\rho)\ln\left(\frac{s_{t+1}}{s_t}\right)\\ &+ \kappa\phi\left[\ln\left(\frac{\tilde{c}_{t+1}}{c_{t+1}}\right)-\ln\left(\frac{\tilde{c}}{c}\right)\right]+\eta_{t+1}\end{aligned}\tag{44}$$

And the linearized Euler equation

$$0=\ln R^X_{t+1}+\ln k_{t+1}$$

becomes

$$\begin{aligned}\kappa\ln\left(\frac{c_{t+1}}{c_t}\right) &= \ln R^X_{t+1}+\ln\beta_{t+1}-\ln(1+\phi)+(\kappa-\rho)\ln\left(\frac{s_{t+1}}{s_t}\right)\\ &+ \kappa\phi\left[\ln\left(\frac{\tilde{c}_{t+1}}{c_{t+1}}\right)-\ln\left(\frac{\tilde{c}}{c}\right)\right]+\eta_{t+1}\end{aligned}$$

Hence we can obtain an empirical version of the consumption Euler equation in the presence of temptation and housing in the utility function:

$$\begin{aligned}\ln\left(\frac{c_{t+1}}{c_t}\right) &= \frac{1}{\kappa}\ln R^X_{t+1}+\frac{1}{\kappa}\ln\beta_{t+1}-\frac{1}{\kappa}\ln(1+\phi)+\frac{\kappa-\rho}{\kappa}\ln\left(\frac{s_{t+1}}{s_t}\right)\\ &+ \phi\ln\left(\frac{\tilde{c}_{t+1}}{c_{t+1}}\right)-\phi\ln\left(\frac{\tilde{c}}{c}\right)+\eta_{t+1}\end{aligned}$$

This equation can be further simplified to get equation (10), which we do rely on in our estimation.

6.6 MA(1) structure of the error terms

We write the estimatable equation as $y = \mathbf{X}\beta + u$, where $\mathbf{X}$ denotes the matrix of k explanatory variables and u is the error term. Given the previously detailed $MA(1)$ error structure, valid instruments are the exogenous variables in $\mathbf{X}$, deterministic contemporaneous variables and second and further lags of remaining variables. Denoting the matrix of instruments by $\mathbf{Z}$ (with more instruments, m than explanatory variables, k), the instrumental estimator I use in the paper is given by the following expression:

$$\widehat{\beta}_{GMM} = [\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X}]^{-1}[\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{y}] \tag{45}$$

and the asymptotic variance-covariance matrix by:

$$\widehat{V}[\widehat{\beta}_{GMM}] = [\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X}]^{-1}[\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}S(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X}][\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X}]^{-1} \tag{46}$$

where S is an $NT \times NT$ block matrix, N denoting the number of cohorts and T the number of time periods the cohorts are observed. Each block on the main diagonal is a $T \times T$ matrix given by the variance-covariance matrix of the residuals of one cohort. Because of the presence of $MA(1)$ structure in the residuals for a particular cohort with parameter -1, these matrixes have nonzero elements in the main diagonal and the first off-diagonals. The off-diagonal blocks of S represent the correlation of residuals of different cohorts. We assume that only contemporaneous correlation is possible, hence these matrices are diagonal.

For each cohort we can find the first-off diagonal elements if we calculate the covariances between the error in given period and the period before/after. The error term in equation (27) has two elements: the MA(1) term which represents the measurement errors plus the white noise component.

$$u_{t+1} = me_{t+1} - me_t + v_{t+1}$$

where me refers to the measurement in period t and v to the white noise component (with given variance σ_v^2). We assume that the measurement error is also a random variable with zero mean and given variance (σ_{me}^2). Hence

$$\mathbb{E}(u_{t+1}) = 0$$

the variance is

$$\begin{aligned} Var(u_{t+1}) &= \mathbb{E}[(u_{t+1}-0)(u_{t+1}-0)] \\ &= \mathbb{E}[(me_{t+1}-me_t+v_{t+1})(me_{t+1}-me_t+v_{t+1})] \\ &= \sigma_v^2+2\sigma_{me}^2 \end{aligned}$$

and the covariance becomes

$$\begin{aligned} Cov(u_{t+1},u_t) &= \mathbb{E}[(me_{t+1}-me_t+v_{t+1})(me_t-me_{t-1}+v_t)] \\ &= -\sigma_{me}^2 \end{aligned}$$

6.7 EIS under temptation preferences

It needs a bit of derivation to prove that the response of consumption growth to the real interest rate change indeed has to be greater under temptation preferences. Let's first take the total derivative of the Euler equation (27) with respect to the real interest rate.

$$\frac{\partial\Delta\ln(c_{t+1})}{\partial r_{t+1}^X} \approx \theta_1\frac{\partial\ln(1+r_{t+1}^X)}{\partial r_{t+1}^X}+\theta_2\frac{\partial\Delta\ln(s_{t+1})}{\partial r_{t+1}^X}+\theta_3\left(\frac{\partial\ln\tilde{c}_{t+1}}{\partial r_{t+1}^X}-\frac{\partial\ln c_{t+1}}{\partial r_{t+1}^X}\right)+\gamma'\frac{\partial\Delta z_{t+1}}{\partial r_{t+1}^X}$$

The only difference here, compared to the same relationship derived from a model with standard preferences is the term corresponds to parameter θ_3. Therefore this is the term which leads to the result of doubled elasticity of intertemporal substitution. Lets now restrict our attention to the effect of the real interest rate and the temptation on change in consumption growth. In Table 6 I show the exercise of explaining the observed data with the two different models. In case we observe 1% increase in the real interest rate and 0.8% increase in the consumption growth for example, the standard model could explain this with an elasticity of substitution parameter of 0.8. The same observation under temptation preferences though would predict an EIS of around 1.5. In this case though, there is the additional term capturing temptation, with estimated parameter (θ_3) of 0.05. These estimated parameters predict that the temptation term has to has to decrease by 14% in order to be able to match the data.

	$\frac{\partial\Delta\ln(c_{t+1})}{\partial r_{t+1}^X}$	$\approx\theta_1\frac{\partial\ln(1+r_{t+1}^X)}{\partial r_{t+1}^X}$	$+\theta_3\left(\frac{\partial\ln\tilde{c}_{t+1}}{\partial r_{t+1}^X}-\frac{\partial\ln c_{t+1}}{\partial r_{t+1}^X}\right)$
Standard	0.8%	$\approx 0.8\cdot 1\%$	
Temptation	0.8%	$\approx 1.5\cdot 1\%$	$+0.05\cdot(-14\%)$

Table 6: ESTIMATES OF PARAMETERS

Recall

$$\tilde{c}_{t+1} = x_{t+1} + \delta Q_{t+1} h_{t+1}$$

Now I write the unit house price as the present discounted value of future stream of housing service in terms of consumption goods, assuming that the interest rate is persistent.

$$Q_{t+1} = \sum_{j=0}^{\infty} \left(\frac{1}{1 + r^X_{t+1}} \right)^j bp \tag{47}$$

where p is the relative price of housing service compared to nondurable consumption. The relative price can be written as the fraction of the marginal utility of housing service and the marginal utility of consumption. For the ease of derivation, I assume that the relative price is constant over time.

$$p = \frac{\partial u_s}{\partial u_c}$$

Now using the formula for the sum of geometric series, we get the following simple expression for the unit house price

$$Q_{t+1} = \frac{1 + r^X_{t+1}}{r^X_{t+1}} bp \tag{48}$$

References

Angelini, Viola, Agar Brugiavini, and Guglielmo Weber. 2009. "Ageing and Unused Capacity in Europe: Is There an Early Retirement Trap?" *Economic Policy* 59:453–508.

Attanasio, Orazio P., James Banks, Costas Meghir, and Guglielmo Weber. 1999. "Humps and Bumps in Life-Time Consumption." *Journal of Business and Economics Statistics* 17(1):22–35.

Attanasio, Orazio P., Renata Bottazzi, Hamish Low, Lars Neisham, and Matt Wakefield. 2012. "Modeling the Demand for Housing over the Lifecycle." *Review of Economic Dynamics* 15 (1):10–53.

Attanasio, Orazio P. and Martin Browning. 1995. "Consumption over the Life Cycle and over the Business Cycle." *American Economic Review* 85(5):1118–1137.

Attanasio, Orazio P. and Hamish Low. 2004. "Estimating Euler Equations." *Review of Economic Dynamics* 7(2):405–435.

Attanasio, Orazio P. and Susann Rohwedder. 2003. "Pension Wealth and Household Saving: Evidence from Pension Reforms in the United Kingdom." *American Economic Review* 93(5):1499–1521.

Attanasio, Orazio P. and Guglielmo Weber. 1993. "Consumption Growth, the Interest Rate and Aggregation." *Review of Economic Studies* 60(3):631–649.

———. 1995. "Is Consumption Growth Consistent with Intertemporal Optimization? Evidence from the Consumer Expenditure Survey." *Journal of Political Economy* 103(6):1121–1157.

———. 2010. "Consumption and Saving: Models of Intertemporal Allocation and Their Implications for Public Policy." *Journal of Economic Literature* 48:693–751.

Bajari, Patrick, Phoebe Chan, Dirk Krueger, and Daniel Miller. 2012. "A Dynamic Model of Housing Demand: Evidence and Policy Implications." *International Economic Review* 54:409–442.

Banks, James, Richard Blundell, and Agar Brugiavini. 2001. "Risk Pooling, Precautionary Saving and Consumption Growth." *Review of Economic Studies* 68 (4):757–779.

Banks, James, Richard Blundell, and Sarah Tanner. 1998. "Is There a Retirement-Savings Puzzle?" *American Economic Review* 88 (4):769–788.

Battistin, Erich, Agar Brugiavini, Enrico Rettore, and Guglielmo Weber. 2009. "The Retirement Consumption Puzzle: Evidence from a Regression Discontinuity Approach." *American Economic Review* 99(5):2209–2226.

Bernheim, B.Douglas. 1995. "Do Households Appreciate Their Financial Vulnerabilities? An Analysis of Actions, Perceptions, and Public Policy." *Tax Policy and Economic Growth* :1–30.

Beshears, John, James J. Choi, David Laibson, Brigitte C. Madrian, and Jung Sakong. 2011. "The Demand for Commitment: Evidence from a Savings Experiment." *NBER Working Paper* .

Blundell, Richard, Luigi Pistaferri, and Ian Preston. 2008. "Consumption Inequality and Partial Insurance." *American Economic Review* 98 (5):1887–1921.

Browning, Martin, Angus Deaton, and Margaret Irish. 1985. "A Profitable Approach to Labour Supply and Commodity Demands over the Life-Cycle." *Econometrica* 53 (3):503–544.

Bucciol, Alessandro. 2012. "Measuring Self-Control Problems: A Structural Estimation." *Journal of the European Economic Association* 10(5):1084–1115.

Carroll, Christopher D. 1992. "The Buffer-Stock Theory of Saving: Some Macroeconomic Evidence." *Brookings Papers on Economic Activity* 1992(2):61–156.

———. 1997. "Buffer-Stock Saving and he Life Cycle/Permanent Income Hypothesis." *The Quarterly Journal of Economics* 112(1):1–55.

Carroll, Christopher D. and Andrew A. Samwick. 1997. "The Nature of Precautionary Wealth." *Journal of Monetary Economics* 40(1):41–71.

Carroll, Christopher D. and Lawrence H. Summers. 1991. "Primary Surpluses and Sustainable Debt Levels in Emerging Market Countries." In national saving and economic performance, edited by B. Douglas Bernheim and John B. Shoven, Chicago: Univ.Chicago Press (for NBER).

Cocco, João F., Francisco J. Gomes, and Pascal J. Maenhout. 2005. "Consumption and Portfolio Choice over the Life Cycle." *The Review of Financial Studies* 18(2):491–533.

Deaton, Angus. 1985. "Panel Data from the Time Series of Cross-Sections." *Journal of Econometrics* 30:109–126.

———. 1991. "Saving and Liquidity Constraints." *Econometrica* 59(5):1221–1248.

DeJong, David and Marla Ripoll. 2007. "Do Self-Control Preferences Help Explain the Puzzling Behavior of Asset Prices?" *Journal of Monetary Economics* 54 (4).

Gourinchas, Pierre-Olivier and Jonathan A. Parker. 2002. "Consumption over the Life Cycle." *Ecpnpmetrica* 70(1):47–89.

Gul, Faruk and Gul Pesendorfer. 2005. "The Revealed Preference Theory of Changing Tastes." *Review of Economic Studies* 72:429–448.

Gul, Faruk and Wolfgang Pesendorfer. 2001. "Temptation and Self-Control." *Econometrica* 69 (6):1403–1435.

Hall, Robert E. 1978. "Stochastic Implications of the Life Cycle-Permanent Income Hypothesis: Theory and Evidence." *Journal of Political Economy* 96:971–987.

Harris, Christopher and David Laibson. 2001. "Dynamic Choices of Hyperbolic Consumers." *Econometrica* 69:935–957.

Huang, Kevin X.D., Zheng Liu, and Qi Zhu. 2013. "Temptation and Self-Control: Evidence from the Consumer Expenditure Survey." *Federal Reserve Bank of San Fransisco* Working Paper 2013-23.

Hurd, Michael D. 1989. "Mortality Risk and Bequest." *Econometrica* 57:779–813.

Judd, Kenneth. 1998. "Numerical Methods in Economics." *The MIT Press* Cambridge, Massachusetts.

Kovacs, Agnes. 2013. "Temptation and Housing: A Structural Estimation." Mimeo.

Laibson, David. 1997. "Golden Eggs and Hyperbolic Discounting." *Quarterly Journal of Economics* :443–477.

———. 1998. "Life-cycle Consumption and Hyperbolic Discount Functions." *European Economic Review Papers and Proceedings* 42(3-5):861–871.

Lettau, Martin and Sydney Ludvigson. 2001. "Resurrecting the (C)CAPM: A Cross-Sectional Test When Risk Premia are Time-Varying." *Journal of Political Economy* 109:1238–1287.

Li, Wenli and Rui Yao. 2007. "The Life-Cycle Effects of House Price Changes." *Journal of Money, Credit and Banking* 39:1375–1409.

Moffitt, Robert. 1993. "Identification and estimation of dynamic models with a time-series of repeated cross-sections." *Journal of Econometrics* 59:99–123.

Phelps, Edmund and Robert A. Pollak. 1968. "On Second-Best National Saving and Game-Equilibrium Growth." *The Review of Economic Studies* 35:185–199.

Piazzesi, Monika, Martin Schneider, and Selale Tuzel. 2007. "Housing, Consumption and Asset Pricing." *Journal of Financial Economics* 83(3):531–569.

Strotz, Robert H. 1956. "Myopia and Inconsistency in Dynamic Utility Maximization." *The Review of Economic Studies* 23:165–180.

Thaler, Richard H. and Shlomo Benartzi. 2004. "Save More Tomorrow: Using Behavioral Economics to Increase Employee Saving." *Journal of Political Economy* 102:S164–S187.

Wartenbroch, Klaus. 1998. "Consumption and Self-Control by Rationing Purchase Quantities of Virtue and Vice." *Marketing Science* 17 (4):317–337.

Zeldes, Stephen P. 1989. "Consumption and Liquidity Constraints: An Empirical Investigation." *Journal of Political Economy* 97:305–346.