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Estimating Temptation and Commitment Over the Life-Cycle[*]

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Abstract

This paper estimates the importance of temptation (Gul and Pesendorfer, 2001) for consumption smoothing and asset accumulation in a structural life-cycle model. We use two complementary estimation strategies: first, we estimate the Euler equation of this model; and second we match liquid and illiquid wealth accumulation using the Method of Simulated Moments. We find that the utility cost of temptation is one-quarter of the utility benefit of consumption. Further, we show that allowing for temptation is crucial for correctly estimating the elasticity of intertemporal substitution: estimates of the EIS are substantially higher than without temptation. Finally, our Method of Simulated Moments estimation is able to match well the life-cycle accumulation profiles for both liquid and illiquid wealth only if temptation is part of the preference specification. Our findings on the importance of temptation are robust to the different estimation strategies.

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

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1 Introduction

'Present bias' has recently received much attention from economists, psychologists and policy makers. The difficulties individuals might have in planning for the future, to delay gratification to access higher returns on investments, or even to accumulate resources to finance consumption in the future, have been extensively discussed. In the context of life-cycle saving decisions, immediate gratification might lead individuals to save much less than they planned to save (see for instance Bernheim (1995)). However, individuals who understand this tendency might have a demand for commitment devices - illiquid assets such as retirement plans or housing - to implement their optimal savings plans (see Strotz (1956), Laibson (1997)). These types of behavior are inconsistent with the standard model of intertemporal choice where instantaneous utility depends only on chosen alternatives and where individuals discount the future geometrically.

Two alternative preference structures that exhibit present bias have received considerable attention. The 'temptation model' proposed by Gul and Pesendorfer (2001) relaxes the standard model's assumption about instantaneous utility so that instantaneous utility depends partly on feasible alternatives that are not chosen, but which are tempting. By contrast, the '$\beta - \delta$' model, formally introduced by Phelps and Pollak (1968), relaxes the assumption of the standard model on discounting and introduces 'hyperbolic discounting', where the discount rate is different in the short and long run. The Gul-Pesendorfer framework has two main advantages as a framework for testing present bias. First, temptation preferences induce dynamically consistent choices. Second, the importance of temptation preferences can be tested directly in a simple linearized Euler equation framework.

The aim of this paper is to provide a quantitative assessment of temptation preferences in explaining consumption and wealth accumulation by introducing temptation into a life-cycle model with liquid and illiquid wealth accumulation. Temptation, as introduced by Gul and Pesendorfer (2001), is the idea that households may be tempted to consume their available liquid resources in each period, and that resisting this temptation is costly. This results in higher current consumption. In a dynamic context, current consumption is raised further as households reduce savings to avoid costly temptation tomorrow, thus distorting consumption smoothing. To alleviate the cost of temptation while still accumulating wealth for both precautionary and life-cycle motives, households may lock away their wealth in housing, which is partially illiquid and therefore may reduce temptation. We assess the importance of temptation preferences in two stages: first, we identify the strength of temptation by estimating the underlying preference parameters using an Euler equation; second, we show the extent that allowing for temptation is necessary for the model to match life-cycle wealth profiles.

In the first part of the paper, we develop a dynamic structural model of consumer demand for housing and consumption with temptation preferences. We derive the model-implied log-linearised consumption Euler equation, then we estimate the model's preference parameters and test for temptation using the Consumer Expenditure Survey (CEX) and synthetic panel techniques. We estimate the importance of temptation, as well as the curvature of the utility function which determines the elasticity of intertemporal substitution. We find a significant effect of temptation on actual choices: the weight on temptation is about a quarter of the weight on consumption, in utility terms. This finding implies that temptation introduces a motive to consume more now because resisting temptation is costly. We also show that estimating the Euler equation without temptation generates a serious omitted variable bias that leads to underestimation of the consumption elasticity of intertemporal substitution parameter (EIS). Allowing for temptation results in an estimate of the EIS of 1.2, but when we do not allow for temptation, we estimate the EIS to be only 0.6.[1]

In the second part of the paper we numerically solve and estimate the full structural model, imposing different assumptions on whether temptation forms part of preferences. Using the Method of Simulated Moments, we estimate the discount factor, and for robustness re-estimate the EIS and the temptation parameter, by matching moments of the life-cycle profiles describing liquid wealth, illiquid housing wealth and consumption. We find that the estimates of the EIS and the temptation parameter are very similar to those estimated in the Euler equation despite the sources of variation being different. These results confirm that our parameter estimates do not vary with the estimation method used. We also estimate the model without allowing for temptation. Using the estimated parameters in the two versions of the model, we demonstrate that allowing for temptation is important for the model to simultaneously match low levels of liquid wealth and high levels of illiquid housing wealth observed in the data. Without temptation, the best fit of the model leads to over-accumulation of liquid wealth and under-accumulation of housing wealth compared to the data.

In our basic model without temptation, the split between illiquid and liquid wealth accumulation is determined by relative returns. By contrast, in the model with temptation, there is an additional motive to accumulate in illiquid housing because of the value of housing as a commitment device. Realizing that temptation occurs in subsequent periods, households will lock away their saving in the form of partially illiquid housing to reduce the cost of resisting temptation in the future. We show how changes in moving costs affect demand for housing. Increasing the fixed cost has a direct effect reducing the consumption smoothing value of housing, but an offsetting indirect effect of increasing

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[1]This estimate is in line with others in the literature of traditional Euler equation estimation. See for example Attanasio and Weber (1993), Blundell, Browning, and Meghir (1994).

the commitment value of housing. We show that this indirect effect dominates and demand for housing rises, especially among the young, when individuals face higher fixed costs.

The main contribution of this paper is to estimate the strength of temptation preferences in a life-cycle context. In this regard, the closest papers to this one are Bucciol (2012) and Huang, Liu, and Zhu (2015). Bucciol (2012) estimates the importance of the temptation motive and finds that the utility weight on temptation is only 5% of the utility weight on consumption. This is in contrast to Huang, Liu, and Zhu (2015) who obtain an estimate of 19%. In this paper, we estimate the utility weight of temptation to be 22%. Relative to this literature, there are three substantial differences in the contribution of our paper. First, we use two different estimation methods and show that our estimates are consistent across methods. Second, we show how ignoring temptation leads to biased EIS estimates. Third, we model explicitly how housing can be used as a commitment device in the presence of temptation; and explore the empirical implications of this perspective. Our decision to study housing explicitly is important in explaining the difference between our estimates and Bucciol (2012), as the latter paper estimates temptation using a definition of illiquid wealth that includes only retirement accounts.

By estimating the importance of temptation, this paper contributes to the growing literature that incorporates temptation preferences in a variety of applied contexts. For instance, Amador, Werning, and Angeletos (2006) study minimum-saving policies in the presence of temptation. Krusell, Kuruşçu, and Smith (2010) show that a savings subsidy would be welfare improving when households suffer from temptation. Schlafmann (2016) uses temptation preferences to understand housing and mortgage choices and the welfare consequences of mortgage regulations. Her results show that households with higher temptation are less likely to become home owners, but higher down-payment requirements could be beneficial to these households. Kovacs and Moran (2019) and Kovacs and Moran (2020) apply the temptation framework of the current paper to two different applications. The first application (Kovacs and Moran, 2019) shows that temptation and commitment can account for the large share of hand-to-mouth households and generate realistic heterogeneity in the marginal propensity to consume. The second application (Kovacs and Moran, 2020) extends the current framework by adding in the possibility of home equity withdrawal, using this framework to evaluate the costs and benefits of financial liberalisation that gives households greater access to home equity.

Finally, our findings complement the growing literature that evaluates the importance of commitment. Direct evidence of demand for commitment has been found in a variety of different contexts. Thaler and Benartzi (2004) report evidence of people committing in advance to allocate a portion of their future salary increase towards re-

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tirement savings. Ashraf, Karlan, and Yin (2006) find a significant increase in saving by consumers who purchased a commitment savings product. Beshears et al. (2020) report that people who have access to both liquid and less liquid accounts, allocate more savings to the less liquid, commitment account. On the importance of housing as a commitment device, Angelini et al. (2020) build a life-cycle model with temptation preferences and conclude that housing is heavily used as a commitment device in later life. In contrast, Ghent (2015) develops a life-cycle model with $\beta - \delta$ preferences and concludes that the commitment role of housing is not an important determinant of housing decisions. Our paper contributes to this literature by directly estimating a model in which housing may serve as a commitment device.

The rest of the paper is organized as follows. In Section 2, we describe the model with temptation preferences. In Section 3, we derive the log-linear form of the Euler equation with temptation preferences, discuss the identification of temptation, and describe the data we use. In Section 4, we report the Euler equation estimation results with and without temptation. In Section 5, we re-estimate the model using MSM, compare these results to our Euler equation estimates, and evaluate the implications for housing as a commitment device. In Section 6, we conclude the paper.

2 A Life-Cycle Model with Temptation Preferences

We start with a simple life-cycle model of consumption and housing in a dynamic stochastic framework. In order to capture the potential commitment benefit of housing, we allow for the possibility that households suffer from self-control problems due to temptation preferences. We then estimate the strength of temptation using CEX data.

The basic framework is as follows. Households live for T periods as adults, of which W periods are spent as workers and $T - W$ periods as retirees. They maximize their present discounted lifetime utility, which depends on nondurable consumption and the consumption of housing services. Households can reallocate resources between periods by investing in liquid assets or partially illiquid housing. Households are allowed to borrow using fixed-rate mortgages, which are collateralized against the value of their house. Households face idiosyncratic uncertainty over their labor income.[2]

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[2]We focus on how temptation affects working-age housing, saving and consumption behaviour, rather than behaviour in retirement. This retirement behaviour may well be important, as discussed in Angelini et al. (2020) and Angeletos et al. (2001), but retirement has multiple additional complications beyond the scope of this paper.

Preferences. The period utility function follows the theoretical, axiomatic-based temptation preferences introduced by Gul and Pesendorfer (2001)[3]:

$$U(C_t, S_t, \tilde{C}_t) = u(C_t, S_t) - \left[\nu(\tilde{C}_t, S_t) - \nu(C_t, S_t)\right] \tag{1}$$

where C_t is the chosen level of nondurable consumption; $\tilde{C}_t$ is the most tempting nondurable consumption alternative given the current choice set; and S_t is the flow of housing services. $u(\cdot)$ and $\nu(\cdot)$ are two von Neumann-Morgenstern utility functions representing two different rankings over alternatives.

According to temptation preferences, utility depends not only on your actual choice, but also the most tempting feasible alternative. The term in square brackets in equation (1) reflects the utility cost of self-control. This is defined as the difference between the temptation utility of the most tempting consumption alternative $\tilde{C}_t$ and chosen consumption C_t. As a result of this specification, households may receive disutility from deviating from the most tempting consumption alternative.

The most tempting consumption alternative, $\tilde{C}_t$, is to spend all available resources on nondurable consumption, which maximizes instantaneous utility:

$$\tilde{C}_t = \arg\max_{C_t}(\nu(C_t; S_t)), \tag{2}$$

subject to the budget constraint, to be defined later. Temptation is over the choice of consumption, rather than housing service flow. This distinction is imposed because housing services, S_t, are predetermined in period t.[4]

According to this preference specification, households may be tempted to maximize current period utility instead of maximizing discounted lifetime utility. Each period, households can decide to exercise self-control or succumb to temptation. If households exercise self-control, they suffer the utility cost of temptation given by equation (1). On the other hand, if households succumb to temptation by choosing $C_t = \tilde{C}_t$, the cost of self-control becomes zero as the utility function simplifies to:

$$U(C_t, S_t, \tilde{C}_t) = u(\tilde{C}_t, S_t) - \left[\nu(\tilde{C}_t, S_t) - \nu(\tilde{C}_t, S_t)\right] = u(\tilde{C}_t, S_t)$$

The implication of this preference formation in our dynamic framework is that succumbing to temptation provides a reward in the short run, but there is a resulting penalty in the long run because resources have been spent early.

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[3]The formal description of the Gul-Pesendrofer model is in Appendix A.1.

[4]In real life, the consumption of housing services is very different from the consumption of other goods and services. Housing services are determined at the point when the home is purchased, and are predetermined in subsequent periods, as discussed further in Section 2.3.

We assume that the functional form for utility, u, is a CRRA function of the composite good, which is a Cobb-Douglas aggregate of nondurable consumption and housing services, following Landvoigt, Piazzesi, and Schneider (2015) among others. The temptation utility function, ν, is simply a rescaled CRRA utility function, following Gul and Pesendorfer (2004):

$$
\begin{aligned}
u(C_t, S_t) &= \frac{(C_t^\alpha S_t^{1-\alpha})^{1-\rho}}{1-\rho} \\
\nu(C_t, S_t) &= \lambda \frac{(C_t^\alpha S_t^{1-\alpha})^{1-\rho}}{1-\rho}
\end{aligned}
\tag{3}
$$

where $0 \leq \alpha \leq 1$ is the weight of nondurable consumption in the composite good, $\rho \geq 0$ is the inverse of the elasticity of intertemporal substitution (for the composite good) and $\lambda \geq 0$ is the degree of absolute temptation. The degree of absolute temptation measures the cost of not succumbing to the tempting alternative. Notice that preferences are standard when $\lambda = 0$. In addition, the larger is λ, the greater is the temptation faced by households and the higher is the utility cost of self-control.

Housing. Households enter each period with housing stock H_t, which yields instantaneous utility, S_t. Households then decide on their housing stock for next period, H_{t+1}, at the same time they make their consumption decision, C_t. We make the simplifying assumption that housing is a discrete rather than a continuous asset, as is common in the literature that incorporates housing into life-cycle models of consumption and saving behavior (see for instance Chambers, Garriga, and Schlagenhauf, 2009; Attanasio et al., 2012; Gorea and Midrigan, 2017; Nakajima and Telyukova, 2020). We assume that there are N available house sizes, which generate increasing amounts of housing services. While households are allowed to own any of the N available house sizes, they can only rent the smallest available housing option, thus housing markets are segmented. The available housing options are $\{H^0, H^1, ..., H^N\}$, where H^0 refers to rental housing and H^i for $i \in \{1, ..., N\}$ refers to owner-occupied housing of type i. We assume that there is a linear technology between the house value and the housing services it provides:

$$
S_t = \begin{cases} \mu_t & \text{if } H_t = H^0 \\ \\ bP_t(H_t) & \text{if } H_t \neq H^0 \end{cases}
\tag{4}
$$

where μ_t is the service flow of renting; $P_t(H_t)$ is the price of house $H_t \in \{H^1, ..., H^N\}$; and b is the rate of service flow. The timing of equation (4) means that housing services are predetermined in each period, because the service value is tied to the start of period

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housing stock.

Rental housing provides a service flow $\mu_t = bP_t(H^1)$ equal to that of the smallest possible house H^1. Rental housing requires a rental payment each period that is equal to the housing service flow μ_t.

House prices increase deterministically according to the following rule:

$$P_t(H^i) = R^H P_{t-1}(H^i) \quad \text{for} \quad \{i = 1, 2, .., N\} \tag{5}$$

Housing plays a special role in the model: it is partially illiquid and as such may serve as a commitment device. The illiquidity of housing is captured by assuming that buying and selling housing comes at a cost, which is a fraction F of the house value. Although households cannot entirely eliminate temptation by putting their wealth into housing, they can partially reduce temptation using housing, as accessing housing wealth for immediate consumption is more costly than accessing liquid wealth.[5]

Mortgages. Housing purchases are financed using long-term, fixed-rate mortgages with mandatory amortization. This captures the type of mortgage used by the vast majority of American households. Mortgages are collateralized to the value of the house and require a down-payment of ψ fraction of the house price. For simplicity, we assume that all households take out the largest possible mortgage $(1 - \psi)P_t(H_{t+1})$ at the time of home purchase. Mortgages are assumed to have a fixed interest rate, R^M, which is the predominant type of mortgage contract in the US. The law of motion for the mortgage stock is as follows

$$M_{t+1} = R^M \begin{cases} M_t - \xi_t & \text{if } H_{t+1} = H_t \\ \\ (1 - \psi)P_t(H_{t+1}), & \text{if } H_{t+1} \neq H_t \end{cases} \tag{6}$$

where ξ_t is the fixed mortgage repayment that households must make in period t, based on the terminal condition that mortgages must be paid off by retirement.[6] By assuming that all mortgages must be paid off by a certain period, we are able to model fully-amortizing mortgages without the need for an additional state variable that captures the remaining maturity of the mortgage.[7] Furthermore, by assuming that all housing

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[5]The commitment benefit of housing comes from the transaction cost of selling. We include transaction costs for both buying and selling to capture the various costs associated with housing transaction regardless of the commitment channel.

[6]Based on this terminal condition, and the assumption that households make equal mortgage payments each year, we can compute the mandatory mortgage payment, ξ_t, using equation (6). This yields a fixed mortgage payment of $\xi_t = M_t \frac{(R^M)^j}{\sum_{i=1}^{j-1}(R^M)^i}$, given mortgage balance (M) and the remaining length of the mortgage (j), which we set to be the number of years until retirement.

[7]In our data, 16% of retirees hold some mortgage debt. Further, Lusardi, Mitchell, and Oggero

purchases are financed with a mortgage equal to the loan-to-value constraint, which is then gradually paid back using a mandatory amortization schedule, we are able to model standard mortgages without the need for an additional choice variable.[8]

Budget Constraint. Households start each period t with a given amount of liquid asset A_t, housing stock H_t, mortgage balance M_t and labor income Y_t. Households then decide on consumption C_t and next-period housing H_{t+1}. By deciding on consumption and housing, households determine how much to save in liquid assets. Next period liquid assets, A_{t+1}, are consequently the end of period liquid assets augmented by the rate of return, R_{t+1}.[9] The intertemporal budget constraint therefore can be written as

$$A_{t+1} = R_{t+1} \begin{cases} A_t + Y_t - C_t - \mu_t - \mathbb{I}_{H_{t+1} \neq H_t}\left[(1+F)P_t(H_{t+1}) - \frac{M_{t+1}}{R^M}\right] \\ \qquad \text{if renter } (H_t = H^0) \\ \\ A_t + Y_t - C_t - \mathbb{I}_{H_{t+1}=H_t}\xi_t \\ + \mathbb{I}_{H_{t+1} \neq H_t}\left[(1-F)P_t(H_t) - M_t - (1+F)P_t(H_{t+1}) + \frac{M_{t+1}}{R^M}\right] \\ \qquad \text{if homeowner } (H_t \neq H^0) \end{cases} \tag{7}$$

The first row in equation (7) holds for households who start period t as renters. These households start the period with liquid assets and income, then pay for consumption and rent. If they purchase a house for next period, they must make a down-payment equal to the the price of the house augmented by transaction costs $(1+F)P_t(H_{t+1})$ net of the initial mortgage $\frac{M_{t+1}}{R^M}$.

The second row in equation (7) holds for households who start period t as home-owners. If these households decide to stay in the same house, they pay the mandatory mortgage payment ξ_t. If they decide to sell their home and become renters, they liqui-date their home equity, equal to the house price net of transaction costs $(1-F)P_t(H_{t+1})$, minus the outstanding mortgage balance M_t. Finally, if a homeowner decides to pur-chase a different home, they liquidate their current home equity, then pay for their new home net of the initial mortgage.

(2018) shows that indebtedness in the decade before retirement has increased over the past 30 years. The issues around retirement and housing are potentially very interesting and there may be interactions between commitment and mortgage choices in retirement that we do not capture.

[8]Kovacs and Moran (2020) extend the current framework in order to evaluate the welfare conse-quences of greater access to home equity withdrawal due to financial liberalisation.

[9]R_{t+1} represents gross real interest rate between periods t and $t+1$, $R_{t+1} = 1 + r_{t+1}$.

Tempting Resources. We can use the budget constraint to define the most tempting consumption alternative, based on the current period optimization problem given by equation (2). We assume that the most tempting consumption alternative, $\tilde{C}_t$, is for households to spend all available resources in t by setting $A_{t+1} = 0$, $H_{t+1} = H^0$ and $M_{t+1} = 0$.[10] We refer to the maximum resources that are available for immediate consumption as tempting resources.

$$
\tilde{C}_t \;=\; \begin{cases} A_t + Y_t - \mu_t & \text{if renter } (H_t = H^0) \\[2em] A_t + Y_t + (1 - F)P_t(H_t) - M_t & \text{if homeowner } (H_t \neq H^0) \end{cases} \tag{8}
$$

The first row in equation (8) holds for households who start period t as renters. For these households, tempting resources are the sum of liquid savings and income net of rent. The second row in equation (8) holds for households who start period t as homeowners. For these households, the most tempting consumption alternative is to liquidiate their home equity and consume it today. As a result, their tempting resources are the sum of liquid savings, income and home equity net of housing transaction costs. While we assume in our baseline analysis that home equity results in temptation, we evaluate sensitivity to this assumption in Section 4.2.

Sources of Uncertainty. Households face uncertainty only through idiosyncratic uncertainty over labor income. We have assumed that house prices are deterministic to focus on the role that housing plays when temptation is present, rather than the role of housing as part of a portfolio allocation decision.

We assume that households' labor income Y_t at any time before retirement is exogenously described by a combination of deterministic and stochastic components. In this subsection, we index the income process by i to distinguish common and idiosyncratic components, although for clarity we have dropped the subscript i from the rest of the exposition.

$$
\ln Y_{i,t} = g_t + z_{i,t} \tag{9}
$$

where g_t is a deterministic age profile common to all households of the same age, while $z_{i,t}$ is the idiosyncratic income component for household i in period t, which is assumed to be an AR(1) Markov-process. Labor income, $Y_{i,t}$, at any time after retirement is a constant fraction a of the last working year's labor income. One can think of this as a

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[10]While we assume that homeowners are always tempted to consume their net housing wealth, we explore sensitivity to this assumption in Section 4.2.

pension that is wholly provided by the employer and/or the state.

$$\ln Y_{i,t} = a + y_{i,W}. \tag{10}$$

Euler Equations. We define the vector of state variables, $\Omega_t = (A_t, Y_t, H_t, M_t)$, and formulate the households' value function in period t in recursive form as:

$$V_t(\Omega_t) = \max_{\{C_t, H_{t+1}\}} U(C_t, S_t, \tilde{C}_t) + \beta \mathbb{E}_t V_{t+1}(\Omega_{t+1}), \tag{11}$$

subject to the budget constraints, the income processes, the form of the utility functions, and the definition of the most tempting consumption alternative.

We derive the Euler equation for consumption assuming that the individual does not give into temptation fully (details in Appendix B.1):

$$\frac{\partial U_t}{\partial C_t} = \mathbb{E}_t \left[\beta R_{t+1} \left(\frac{\partial U_{t+1}}{\partial C_{t+1}} + \frac{\partial U_{t+1}}{\partial \tilde{C}_{t+1}} \right) \right] \tag{12}$$

We substitute in the functional form for the utility function and, following Bucciol (2012), define $\tau = \lambda/(1 + \lambda)$ as the degree of relative temptation which measures the importance of temptation relative to consumption, in consumption utility terms. The Euler equation is then[11]

$$\frac{(C_t^\alpha S_t^{1-\alpha})^{1-\rho}}{C_t} = \mathbb{E}_t \left[\beta R_{t+1} \left(\frac{(C_{t+1}^\alpha S_{t+1}^{1-\alpha})^{1-\rho}}{C_{t+1}} - \tau \frac{(\tilde{C}_{t+1}^\alpha S_{t+1}^{1-\alpha})^{1-\rho}}{\tilde{C}_{t+1}} \right) \right]. \tag{13}$$

This is the key optimising condition which 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. This marginal cost of resisting temptation depends on the importance of temptation, τ, multiplied by the marginal utility of consuming extra tempting resources. The incentive to move resources into period $t+1$ and to increase consumption in period $t+1$ is therefore higher when either the importance of temptation is low or when the marginal utility from consuming tempting resources in $t+1$ is low (ie. when the amount of tempting resources is high).

This Euler equation differs from the standard one in two respects: the traditional Euler equation is derived from a model without housing services in the utility function i.e. with $\alpha = 1$, and without temptation, i.e. with $\tau = 0$. Setting $\alpha = 1$ and $\tau = 0$, equation (13) simplifies to the traditional Euler equation, which is extensively used for

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[11]Note that S_{t+1} is predetermined in period t and so can be taken outside the expectations operator.

estimating the elasticity of intertemporal substitution (EIS) parameter:

$$C_t^{-\rho} = \mathbb{E}_t\left[\beta R_{t+1} C_{t+1}^{-\rho}\right]. \tag{14}$$

We use this life-cycle framework to estimate and simulate behavior in the presence of temptation. In section 3 and 4, we use the optimizing condition (13) to estimate the crucial model parameters: the elasticity of intertemporal substitution and the degree of temptation. In section 5, we use the full model specification in equations (1)-(10) to re-estimate the key model parameters by targeting the life-cycle profiles of consumption, liquid assets and housing.

3 Estimating Temptation and the EIS

The aim of the first part of our empirical analysis is to estimate the degree of temptation, to estimate the elasticity of intertemporal substitution, and further, to show the bias in estimates of the elasticity of intertemporal substitution that arises if we ignore temptation. In this section, first we discuss the linearization to derive an estimating equation; second, we discuss our identification strategy and the instruments used in the estimation; finally, we describe the data used in estimation. Further details of the empirical strategy are in Appendix B.

We estimate the temptation and intertemporal substitution preference parameters directly from the Euler equation. The advantage of using the Euler equation to estimate these parameters is that we can be agnostic about the full life-cycle stochastic environment at this stage. Later, in Section 5, we re-estimate both the temptation and EIS parameters using the full structural model, which provides an alternative identification of these parameter estimates.

3.1 Linearisation of the Euler Equation

We use a log-linearised version of equation (13). There are at least three reasons why we do not estimate the nonlinear equation (13) directly, as discussed in Attanasio and Low (2004). First, they show using Monte-Carlo evidence the poor performance of nonlinear GMM estimates in the small-samples typically available in Euler equation estimation. Second, there is potential measurement error which can be dealt with in a linear model. Finally, we do not have a real panel dataset, but rather use synthetic panel techniques under which proper aggregation requires linearity.

The linearisation of the Euler equation in the presence of temptation is not straightforward. For better understanding, we present the main steps of the derivation here,

while the detailed derivation of the linear approximation can be found in Appendix B.2. First we rewrite the Euler equation (13) for the liquid asset as follows

$$\mathbb{E}_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{\kappa}\right] = \beta\mathbb{E}_t\left\{R_{t+1}\left(\frac{S_{t+1}}{S_t}\right)^{\kappa-\rho}\left[1-\tau\left(\frac{\tilde{C}_{t+1}}{C_{t+1}}\right)^{-\kappa}\right]\right\} \tag{15}$$

with $\kappa = 1-\alpha(1-\rho)$, which is the inverse of the consumption elasticity of intertemporal substitution. The term in the square brackets of the right-hand side shows up under temptation preferences only and depends on the ratio of tempting resources to actual consumption. This highlights the two determinants of the importance of temptation: the degree of relative temptation, τ, and the marginal utility of tempting resources. Log-linearizing equation (15) and expressing in terms of realizations rather than expectations gives:[12]

$$\begin{aligned}\kappa\ln\left(\frac{C_{t+1}}{C_t}\right) &= \ln R_{t+1} - \ln(1+\phi) + (\kappa-\rho)\ln\left(\frac{S_{t+1}}{S_t}\right) \\ &+ \kappa\phi\left[\ln\left(\frac{\tilde{C}_{t+1}}{C_{t+1}}\right) - \ln\left(\frac{\tilde{C}}{C}\right)\right] + \eta_{t+1}\end{aligned} \tag{16}$$

where η_{t+1} contains expectational errors and deviations of second and higher moments of variables from their unconditional means. The parameter ϕ is a function of other model parameters:

$$\phi = \frac{\tau}{\chi^{\kappa}-\tau},$$

where $\chi = \tilde{C}/C$ is the steady state ratio of tempting resources to consumption. In our empirical implementation, we define χ as the median value of $\tilde{C}/C$ across all households and ages.[13]

We can now derive the estimable version of the Euler equation under temptation preferences

$$\ln\left(\frac{C_{t+1}}{C_t}\right) = \theta_0 + \theta_1\ln R_{t+1} + \theta_2\ln\left(\frac{S_{t+1}}{S_t}\right) + \theta_3\ln\left(\frac{\tilde{C}_{t+1}}{C_{t+1}}\right) + \epsilon_{t+1}, \tag{17}$$

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

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[12]The derivation of the log-linearised Euler equation is given in Appendix B.2.

[13]Our use of a fixed χ is an approximation since our underlying framework is a life-cycle model where tempting resources may vary systematically with age. We explore in section 4.2 below how different definitions of χ may affect estimation results, in particular how χ varies with age.

regression coefficients are related to the model parameters as follows:

$$\theta_1 = \frac{1}{\kappa}$$
$$\theta_2 = \frac{\kappa - \rho}{\kappa}$$
$$\theta_3 = \phi = \frac{\tau}{\chi^\kappa - \tau}, \tag{18}$$

where θ_1 is the consumption elasticity of intertemporal substitution. Equation (17) differs from the traditional Euler equation used in the empirical literature: it additionally includes the growth rate of the housing service flow, and the log of the ratio of tempting resources to consumption. The growth of housing service flow plays a role because housing service flow is in the utility function, while the log of tempting resources over consumption enters the equation because of the presence of temptation.

On the other hand, if housing does not change between period t and $t+1$, then the term in S drops out. Alternatively, setting the weight of nondurable consumption in the composite good parameter, α to one, reduces κ to ρ and θ_2 to zero. In either case, equation (17) simplifies to the Euler equation derived from a model with temptation preferences but no housing service in the utility function.

Setting the temptation parameter τ to zero, equation (17) simplifies to the standard Euler equation with housing services in the utility function. In case of setting both τ to zero and α to one, equation (17) becomes the traditional Euler equation with consumption growth on the left-hand side and the log of the gross real interest rate on the right-hand side.

The coefficient estimates of equation (17) can be used to obtain the relative strength of temptation, τ, using the definitions in equation (18). This yields the following functional form for τ:

$$\tau = \chi^\kappa \frac{\theta_3}{1 + \theta_3} \tag{19}$$

As we discuss below, we use a synthetic panel approach to estimation and this means we estimate equation (17) using group averages:

$$\Delta\overline{\ln(C_{t+1})}^g = \theta_0 + \theta_1 \ln(1 + r_{t+1}) + \theta_2 \Delta\overline{\ln(S_{t+1})}^g + \theta_3 \overline{\ln\left(\frac{\tilde{C}_{t+1}}{C_{t+1}}\right)}^g + \gamma'\Delta\overline{Z_{t+1}}^g + u_{t+1} \tag{20}$$

where superscript g denotes group (or cohort) averages.[14] In section 4, we report esti-

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[14]To account for heterogeneity due to observables, we assume that the household's utility is shifted by a number of demographic variables, following Attanasio and Weber (1995). Instantaneous utility function is $U_t = U(C_t)f(Z_t, \gamma)$, where we assume $f(Z_t, \gamma) = \exp(\gamma'Z_t)$. The vector Z_{t+1} includes all of

mates of the Euler equation (20) with and without housing and with and without the possibility of temptation. This is performed by imposing different constraints on the values of α and τ.

3.2   Identification and Instruments

The key regressor for our identification of temptation is the ratio of tempting resources relative to realized consumption in $t+1$, $\frac{\tilde{C}_{t+1}}{C_{t+1}}$. A greater amount of tempting resources, due for example to greater income in $t+1$, will lead to greater consumption growth between t and $t+1$ depending on how much individuals respond to temptation, which is captured by θ_3. By contrast, the amount of tempting resources in period t does not enter the Euler equation because it is a state variable known at the start of period t.

Consumption will be growing between period t and $t+1$ if there is a relative price difference in the real interest rate leading to intertemporal substitution or if individuals suffer from temptation. The coefficient θ_3 contains τ, the importance of temptation, along with the elasticity of intertemporal substitution, which itself is pinned down by the coefficient on the interest rate, θ_1.

The important variation used to pin down θ_3 comes from the ratio of tempting resources, $\tilde{C}_{t+1}$, to actual consumption, C_{t+1}. We use variation over time in the group average of this ratio, as in equation (20). This comes from variation in the average amount of liquid resources within the group, where as discussed in Section 3.3 below, liquid resources includes net wealth in a house that can be readily accessed. The use of time variation in group averages means we are not using individual level variation to identify the impact of tempting resources.[15]

In addition to the identification of θ_3, we consider whether the exclusion of $\tilde{C}$ from the regression will affect the estimates of θ_1. If the regression excludes tempting resources, there is potentially an omitted variable bias. The direction of the bias in the estimate of the elasticity of intertemporal substitution depends on the correlation between tempting resources and the interest rate.

A further issue is the endogeneity of the right-hand side variables of equation (20). The error contains expectation errors because the Euler equation holds in expectation rather than with the realised values. This expectation error is necessarily correlated with the regressors. We therefore need instruments for the interest rate, the growth in housing services, and for tempting resources (as discussed in Appendix B.3). We use lagged values of the group averages as instruments: variables which involve group

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these demographic and labor supply variables, as well as seasonal dummies.

[15]If households succumb to temptation completely and consume all the tempting resources, we cannot identify τ and the consumption growth of households tempted in this way will look identical to credit constrained households.

averaging need to be lagged two or more periods; variables which are aggregate, such as the real interest rate, need only to be lagged one or more periods, as the measurement error in these variables is serially uncorrelated.

3.3   Data

We use the Consumer Expenditure Survey (CEX), which is a household-level micro dataset collected by the Bureau of Labor Statistics (BLS). The BLS 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 a 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 months prior to the interview. Household characteristic variables we consider are family size, the 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 a monthly basis for each household.

Besides household characteristics and expenditures, the CEX also collects detailed information on household income and wealth status. Most importantly it provides rich information on different types of savings, and on rented and owned housing. Homeowners report the approximate value of their houses, while renters report the rental price of their homes. Information on financial assets and dwellings are only gathered in the final interview, leading to one observation per year per household. Given that the CEX excludes households that have moved house, the value of housing in the final interview is likely to be similar across all quarters within the year. We therefore allocate this reported information on rent and house value to the earlier quarters.

We work with quarterly data during the period 1994q1 to 2010q4. We include both homeowners and renters. We exclude non-urban households to ensure comparability with previous estimates (Attanasio and Weber, 1995). We restrict our analysis to households where the head is at least 21 and no more than 60.[16] This yields roughly 249,000 observations (interviews) for around 93,000 households.

Some households do not answer questions related to assets and so we only use data on households who respond to these questions. This generates a potential selection bias: out of roughly 249,000 interviews there are roughly 60,000 with missing savings

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[16]The CEX defines the head as the male in a male-female couple and as the reference person otherwise. Young households are more likely to be exposed to liquidity constraints, while older households' preferences might undergo substantial changes. Therefore the estimation of the coefficients in the Euler equation might be biased for young and old households.

information. We show the extent of selection on observables in Table 1, where we compare characteristics of the sample who report savings information to those where the information is missing. There are negligible differences between the two samples, although those with complete information are slightly older, marginally less educated and in larger families.

Table 1: Comparing means of different samples

	Savings information	
	Missing	Complete
	(1)	(2)
Age	39.85	41.79
Female	0.28	0.26
Black	0.13	0.12
Education	2.91	2.90
Family size	2.74	2.88
Obs.	59,759	188,945

Note: Education is a categorical variable. 1 - High school drop-out. 2 - High school graduate. 3 - College drop-out. 4 - At least college graduate.

Next we construct the variables needed to estimate the Euler equation: nondurable consumption, tempting resources, housing service flow and the real interest rate.

Consumption. We collect the available monthly expenditures data from the *Detailed Expenditures Files (EXPN)* of CEX. We define consumption as all expenditures on nondurable goods and services, except spending on education and health care. We then create quarterly consumption by aggregating monthly expenditures. To avoid the complicated error structure that the timing of the interviews would imply on quarterly data, we take the spending in the month closest to the interview and multiply it by three. We deflate nominal consumption by the consumer price index for nondurables with base-period 1982-1984.

Tempting Resources. Tempting resources represent the maximum amount available for consumption in any given period, as shown by equation (8). This is defined as the sum of liquid wealth, quarterly labor income and net housing wealth subject to a transaction cost of 7% of the gross house value.

The CEX survey collects financial and income information in the last interview, which can be found in the *CU Characteristics and Income File (FMLY)*. The asset categories we include in liquid wealth 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 we can easily calculate the quarterly flow of labor income by dividing that reported amount by four. We deflate all variables by the consumer price index for nondurables.

We calculate the value of net housing wealth for homeowners using the self-reported home value in the *OPB* files (discussed above) and the self-reported outstanding mortgage balance in the *Mortgage (MOR)* files in the survey. Net housing wealth is set to zero for renters.

Calculating the degree of temptation using equation (18) requires the steady state ratio of tempting resources to consumption. To obtain the empirical version of this steady state ratio, χ, we use the CEX and take the median value of tempting resources over nondurable consumption for working-age households, which yields $\chi = 6.44$. However, accumulation of wealth over the life-cycle means that the tempting resources increase with age. In Section 4.2 we explore sensitivity of our parameter estimates to estimating on age sub-groups where the values of tempting resources differ. Section 4.2 also shows how robust our results are to different assumptions about how much of housing wealth counts as tempting resources

Housing Service Flow. Under *Detailed Expenditures Files (EXPN)*, there are two separate files, which contain 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 the approximated value of the house is available for the owned living quarters. For renters, we define quarterly housing service flow to be three times the reported monthly rent. For homeowners, we approximate quarterly housing service with 1.5 percent of the value of housing.[17] Again, we deflate the housing service flow by the consumer price index for nondurables.

Real Interest Rate and Inflation. We 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. We then subtract ex post inflation between quarter $t-1$ and quarter t from the nominal interest rate between quarter $t-1$ and quarter t to get the ex post real interest rate.

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[17]Own calculation based on Bureau of Economics Analysis (BEA) suggests housing service to be around 6.1 percents of the value of housing per year.

Synthetic Panel. The CEX lacks a long time series of observations for the same households. Hence, instead of using the short panel dimension of the dataset, we use the synthetic panel approach to estimate the Euler equation first proposed by Deaton (1985) and Browning, Deaton, and Irish (1985). Details are discussed in Appendix B.3. We define cohorts by year-of-birth, using 5 year windows. Using these cohorts, we estimate a consistently aggregated version of equation (17) for all cohorts simultaneously, giving the estimating equation (20).[18]

4 Euler Equation Estimation Results

In this section, we report estimates of the two key parameters: the degree of temptation and the consumption elasticity of intertemporal substitution. We estimate these parameters using the Euler equation as described above in equation (20), imposing different assumptions on whether housing enters the utility function and whether temptation is allowed.

4.1 Baseline Estimation

We use as instruments the different lags of consumption growth, the growth of housing service flow, nominal interest rates, house price indices and household characteristics. Household characteristics are the age of the household, number of family members who are younger than 2, and a dummy for single households. We report the first stages for these instruments in Table C.1 in the Appendix. We focus on the quality of the instruments for the interest rate, for tempting resources and for housing services. The instruments for the interest rate and for tempting resources have F-statistics of 27 and 324 respectively. On the other hand, the instruments for the growth in housing services are weaker: the F-statistic is 4.6. The difficulty with the growth in housing services is that it is only non-zero for people who report different rental/home values over time. As a consequence of concerns that the instrument for housing growth is weak, we report estimates of our key parameters both including and excluding housing growth from the regression (and utility function). This also implies that our estimates of α, the share of housing in utility, will be imprecise.

Table 2 presents estimates of the Euler equation. The key parameters are shown

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[18]The repeated cross-section structure of the data introduces an MA(1) process to the error term as individuals enter and then drop out of the sample cohort. This means we need to define appropriate instruments to obtain consistent results (as discussed in Appendix B.3). Variables which are individual specific need to be lagged two or more periods. Variables which are aggregate, such as the real interest rate, needs only to be lagged one or more periods, if the measurement error in these variables is serially uncorrelated.

in the first row which reports the consumption elasticity of intertemporal substitution, $(1/\kappa)$ and the final row which reports the implied degree of relative temptation, τ. The four columns correspond to different assumptions about preferences: in columns 1 and 3, housing does not enter the utility function ($\alpha = 0$), and in columns 1 and 2, there is no temptation ($\tau = 0$). Our baseline with both temptation and housing in utility is in column 4.

Table 2: Euler Equation – Estimation Results

	Coefficient in equation (20)	Standard Model		Temptation Model	
		(1)	(2)	(3)	(4)
$\log(1+r)$	θ_1	0.839***	0.582**	1.131***	1.181***
		(0.319)	(0.304)	(0.349)	(0.368)
$\Delta \log(\text{S})$	θ_2		0.159		0.195*
			(0.114)		(0.121)
$\log(\tilde{C}/C)$	θ_3			0.046***	0.048***
				(0.014)	(0.014)
τ				0.229**	0.221**
				(0.107)	(0.099)

Note: Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ All specifications includes a constant, three seasonal dummies, cohort age, single dummy and the number of children below age 2. τ is the relative temptation. When we exclude housing from the utility function, we set $\alpha = 0$, while when we exclude temptation, we set $\tau = 0$. The value of α implied by other parameter estimates is 1.61 (1.40) for the model without temptation and 0.48 (0.74) for the model with temptation.

The Temptation Parameter

One of the strengths of using Gul-Pesendorfer preferences is the ability to test the importance of temptation directly. By contrast, it is harder to test the presence of $\beta - \delta$ preferences in an Euler equation framework because $\beta - \delta$ preferences operate through the discount rate which is not identified in a linearized Euler equation. Testing the empirical existence of temptation is equivalent to testing the null hypothesis that the parameter of relative temptation is zero, $\tau = 0$. The bottom row of Table 2 reports the estimate of τ: the null hypothesis that $\tau = 0$ is rejected.

The estimate for the degree of relative temptation is statistically significant and around 0.22. The parameter of relative temptation can be interpreted easily: the weight on the utility cost of temptation is about a quarter of the weight on the utility benefit of consumption. Our conclusions about the importance of temptation are unaffected by the inclusion or not of housing services in the utility function. This is shown by comparing columns 3 and 4 of Table 2.

Our estimated value of 0.22 is slightly higher than Huang, Liu, and Zhu (2015) who estimate a value of τ equal to 0.19, and it is substantially higher than Bucciol (2012) who estimates $\tau = 0.05$. To check whether our estimates are due to the particular estimation method, we re-estimate the value of τ using the Method of Simulated Moments and the full structural model in section 5. We show that it is not the estimation method that matters, rather different estimates of temptation seem to be due to the source of variation or moments used. The advantage of the Euler equation framework is that it provides a direct way to exploit variation in the availability of tempting resources.

The Consumption Elasticity of Intertemporal Substitution

The top row of Table 1 reports the estimates for the elasticity of intertemporal substitution. When we do not allow for temptation, we obtain estimates of the consumption elasticity of intertemporal substitution between 0.58 and 0.84. These are in the range of those estimated in the literature, such as Attanasio and Weber (1993), Blundell, Browning, and Meghir (1994) or Bucciol (2012). By contrast, when we include temptation, as shown in columns 3 and 4 of Table 2, we estimate the EIS parameters for consumption to be above 1. In the baseline specification the EIS parameter is 1.18.

We interpret the difference in the estimates of the EIS as arising because excluding tempting resources from the Euler equation generates an omitted variable bias. The interest rate has two effects on consumption growth. First, there is a direct effect through the desire to substitute intertemporally in response to relative prices. Second, there is an indirect effect because the amount of tempting resources changes with the interest rate. The derivative of the Euler equation with temptation preferences, equation (20), with respect to the real interest rate shows these two effects:[19]

$$\frac{\partial \Delta \ln(C_{t+1})}{\partial r_{t+1}} \approx \theta_1 + \theta_3 \frac{\partial \ln(\tilde{C}_{t+1}/C_{t+1})}{\partial r_{t+1}} \tag{21}$$

The bias in the estimates of the EIS comes from ignoring the indirect effect of the interest rate. Because we estimate θ_3 to be positive, the lower estimate for θ_1 ignoring temptation implies that $\frac{\partial \ln(\tilde{C}_{t+1}/C_{t+1})}{\partial r_{t+1}} < 0$.

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[19]We ignore housing in the utility function for the ease of understanding the bias introduced by

Table 3: Contemporaneous Correlation with Real Interest Rate

Income	Liquid Wealth	Net Housing Wealth	Tempting Resources
(1)	(2)	(3)	(4)
-0.233	-0.025	-0.163	-0.064

Note: Variables are in logs. Tempting resources are the sum of the individual components, income, liquid wealth and net housing wealth.

In Table 3, we uncover the empirical relationship between the interest rate and the components of tempting resources: we report correlations of each component with the real interest rate. As seen, each component is negatively correlated with the interest rate, which straightforwardly leads to a negative correlation between the real interest rate and the tempting resources themselves.[20]

When the interest rate is high, there are less resources available to tempt households in $t + 1$. However, this means the marginal utility of tempting resources in $t + 1$ is high and so the cost of resisting temptation is high for a given value of τ, the degree of relative temptation. This increases the incentive to consume in t in order to avoid the cost of temptation in $t + 1$, and so the higher interest rate reduces consumption growth. This indirect effect mitigates the direct effect of the interest rate: excluding tempting resources from the Euler equation leads to an underestimate of the EIS.

These conclusions about the effect of allowing for temptation are not affected by the inclusion or exclusion of housing in the utility function: the estimate of the consumption EIS is not significantly different between columns 1 and 2, nor between columns 3 and 4. It is the inclusion of temptation that matters for estimates of the EIS.

4.2 Robustness of the Estimates

We next explore the sensitivity of our estimation results to alternative assumptions about the importance of housing in the calculation of tempting resources $(\tilde{C})$. In our baseline analysis, we define tempting resources to be the sum of liquid assets, quarterly labor income and net housing wealth (minus the housing transaction cost). This assumption

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ignoring temptation.

[20]The negative correlation between income and the real interest rate is a well-known fact in the macro literature, as discussed by King and Watson (1996). Moreover, when the interest rate is high households' net housing wealth is typically lower for two reasons. First, given that the house price is the present discounted value of future housing service flows, the value of a home is negatively affected by higher real interest rates. Second, when real interest rates are high mortgage interest rates are also high, which leads to higher outstanding mortgage balances and lower net housing wealth.

is consistent with the model described in Section 2, reflecting the fact that homeowners may always sell their home if they want to finance additional consumption. Yet we may be concerned that housing wealth results in less temptation than liquid assets, given that it is partially illiquid. We therefore assess the sensitivity of our estimation results to alternative assumptions about the accessibility of housing.

Table 4 shows how parameter estimates vary depending on the share of net housing wealth included in our definition of tempting resources. We evaluate five alternative specifications ranging from 0% to 100%. We find that the estimates of τ range from 0.21 to 0.26. As we increase the share of housing wealth from 25% to 100%, χ increases but the estimate of θ_3 declines, thus τ remains relatively unchanged. Even when housing wealth is fully excluded from tempting resources, the value of τ remains at 0.25. In addition, when housing wealth is excluded from tempting resources, the estimated value of the EIS falls to 0.91, reflecting the omitted variable bias discussed in the previous section.

Table 4: Sensitivity of estimates to net housing wealth

% of NHW included	E.I.S.	θ_3	χ	τ
(1)	(2)	(3)	(4)	(5)
0%	0.91	0.07	3.34	0.25
25%	1.10	0.09	3.59	0.26
50%	1.18	0.06	4.63	0.21
75%	1.18	0.05	5.57	0.21
100%	1.18	0.05	6.44	0.22

Note: This table shows the sensitivity of our estimation results under different assumptions about the accessibility of housing. This affects the estimation of χ, but also has broader implications for how we define $\tilde{C}$ in our regression. Net housing wealth is defined as the house value net of mortgage balances and the housing transaction cost.

We next consider the effect of age on our estimates of the strength of temptation. The reason we explore sensitivity to age is because the median value of tempting resources over consumption (χ) may vary over the life-cycle as households accumulate more wealth, which may affect our estimate of temptation. We evaluate three alternative age groups: those under 35, those under 45 and those under 60, which is our baseline. We use these broad groupings to maintain sample size.

Table 5 reports our parameter estimates for each of these age groups. We find that there is no substantial variation in the estimates of the temptation parameter τ as older households are included in the sample. This is despite the fact that both χ and the

EIS increase as older households are included. The increase in χ indicates that older households have greater tempting resources relative to consumption, while the increase in the EIS suggests that older individuals are more willing to intertemporally substitute consumption.[21] These two parameters have opposite effects on the estimate of τ, as can be seen in equation (19). While χ increases, κ decreases, thus the value of χ^{κ} does not change substantially. As a result, the estimated importance of temptation τ is similar for the different age groups.

Table 5: Sensitivity of estimates to age

Age Group	E.I.S.	θ_3	χ	τ
(1)	(2)	(3)	(4)	(5)
Up to 35	0.82	0.05	3.53	0.22
Up to 45	1.12	0.06	4.69	0.23
Up to 60	1.18	0.05	6.44	0.22

Note: This table reports our parameter estimates for different age groups. We consider households under 35, households under 45 and households under 60, which is our baseline.

4.3 Excess-Sensitivity and Liquidity Constraints

One common direct test of the standard life-cycle model is the excess-sensitivity test that households do not change their consumption in response to changes in predictable income (see for instance Thurow (1969), Flavin (1981), Campbell and Mankiw (1991) and Carroll and Summers (1991)). The finding of excess-sensitivity is interpreted as evidence of the importance of liquidity constraints. Tempted households may be more likely to face binding liquidity constraint than standard households and this would lead to biased estimates of the coefficients in the Euler equation. We address this concern in two ways: first, we test for excess sensitivity in both the standard and temptation specifications; second, we estimate the Euler equation on a sub-group where we would not expect individuals to be liquidity constrained.

We report the results of the excess sensitivity test in columns 1 and 2 of Table 6. Neither in the standard nor temptation model is there evidence of excess sensitivity. This is consistent with Attanasio and Weber (1995) who show that when using data grouped by cohort and controlling for demographics, there is no evidence of excess sensitivity.[22]

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[21]For comparison, we re-estimated the Euler equation for the same age groups but leaving out temptation. We have already shown in our baseline that the EIS is biased downwards when tempting resources are not included. Nonetheless, as with the temptation model, we find that the estimates of the EIS increase with age, with corresponding estimates 0.28, 0.49 and 0.58.

[22]Further, Heckman (1974), Attanasio et al. (1999) and Browning and Ejrnaes (2002), show that by

Table 6: Tests for Liquidity Constraint

	Standard Model	Temptation Model	
	(1)	(2)	(3)
$\log(1+r)$	0.571*	1.163***	1.174***
	(0.322)	(0.384)	(0.371)
$\Delta\log(\text{S})$	0.154	0.184	0.134
	(0.137)	(0.142)	(0.110)
$\log(\tilde{C}/C)$		0.048***	0.039***
		(0.014)	(0.013)
$\Delta\log(\text{Y})$	0.020	0.042	
	(0.235)	(0.246)	

Note: Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ All specifications includes a constant and three seasonal dummies. The first two columns are regressions to test excess sensitivity, while the last column is our baseline Euler equation on a sample of households with liquid asset over $1000.

Column 3 of Table 6 reports the estimates of our baseline temptation model on the subgroup of individuals who have liquid assets over $1000 in any given period (about 60% of the original sample). The changes in the estimate of the EIS and the temptation parameter are not significant.

5   Method of Simulated Moments Estimation

In this section, we numerically solve and estimate the full structural model. We then compare our estimates from the full-structural model to the estimates from the Euler equation in Section 4. Estimation through the Euler equation does not require correct specification of the resource constraints and uses different variation to identify parameters, and so a comparison of the estimates provides evidence of whether our estimates differ by estimation method.

We set the model parameters using the Method of Simulated Moments (MSM) in two stages. In the first-stage, we set parameters outside of our model: some are estimated on the CEX data or from different data sources, while other parameter values are adapted from elsewhere in the literature. In the second-stage, we then choose the discount factor,

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using a more flexible version of the life-cycle model excess sensitivity can be reconciled with intertemporal optimization, for instance by allowing for non-separability between consumption and leisure; or considering changes in the demographic composition of the household.

β, the EIS parameter, and the degree of temptation, τ, in order to minimize the distance between moments from the model and the data, discussed in subsection 5.2 below. We allow for different values of β and the EIS to be estimated separately for the different variants of the model.

5.1   Exogenous Parameters

The exogenous parameters are collected in Table D.3 in the Appendix D.4. In this section, we discuss the source of these exogenous parameters.

House Sizes and House Prices. Identifying the set of house sizes that are available in the data is somewhat problematic because we only observe house prices for those that have chosen to buy. Further, in the data we only observe the current price and not the price at the time of purchase. Nonetheless, we calculate the distribution of house prices for households between age 20 and 30. We use this distribution of house prices to define the different sizes of house, and these sizes are then kept constant over time. However, the price of each size will change following equation (5). In our model, we set the maximum house price (size) at 12 times average income at age 20, corresponding to the 95th percentile of observed house prices for the age group 20-30 in the data, and we set the minimum price at twice average income. We allocate the remaining points on the house size grid to a logarithmic scale, following Nakajima and Telyukova (2020). We assume that there are 5 different house sizes available ($N = 5$). We impose the same house size structure on the temptation model and on the standard model.

Housing Service. We estimate the annual housing service flow over housing stock, b, using data from the Bureau of Economic Analysis (BEA). We use housing gross value added at current dollars to approximate the housing service flow and use residential fixed assets at current dollars to approximate the housing stock.[23] The average of gross housing value added over residential fixed assets over the period 1994-2011 is 8.6%. In order to calculate the net value added over residential fixed assets, we take the depreciation rate for residential capital from the BEA.[24] The depreciation rate is calculated as depreciation divided by housing fixed assets, which is about 2.5% for the period 1994-2011. Consequently, the net value added over residential fixed assets is calculated to be 6.1% over the same period.

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[23]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. 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.

[24]Depreciation for residential capital is taken from the Table 1.3. "Current-Cost Depreciation of Fixed Assets and Consumer Durable Goods" of the BEA Fixed Asset Tables

Non-Housing Consumption Share in the Composite Good. We calculate the share of housing services in total consumption from aggregate data in the same way as we calculate housing service flow from the BEA data. we divide housing services by total consumption net of health and educational expenditures.[25] The average share over the period 1994-2011 is 0.18, thus the share of non-housing consumption is 0.82. This is exactly the value that Piazzesi, Schneider, and Tuzel (2007) report in their paper.

Note that, having estimated the Euler equation, we can directly calculate the parameter α, the share of non-housing consumption in the composite good, using the estimated coefficients, κ, in equation (18). In our baseline specification the point estimate of this share is 0.48 with a large standard error of 0.74, which is not significantly different from the BEA value we calculated.[26] This continues to be true for the alternative specifications, as shown in Table D.1 in the Appendix. Hence, we use the observed share rather than the estimated one.

Income Process. To obtain the age-specific component of the life-cycle income profiles (G), we fit a third-order age polynomial to the logarithm of cohort income data gathered from the CEX.

$$\overline{\ln(y_t)}^g = d_0 + d_1 age_{g,t} + d_2 \frac{age_{g,t}^2}{10} + d_3 \frac{age_{g,t}^3}{100} + u_{g,t}^y \tag{22}$$

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 for the whole sample are presented in Table D.2. For the idiosyncratic income component, z_t, which is an AR(1) Markov-process, we set $\rho = 0.95$ and calibrate σ_z such that the income variance is in line with Low, Meghir, and Pistaferri (2010).

The replacement rate, a, is calculated on the CEX as the ratio of the before- and after-retirement average labor income. Since the normal retirement age is 67 over our sample period[27] but individuals may begin claiming benefits from age 62, we consider 8-year intervals before age 62 and after age 67 in order to calculate these averages. We set the before-retirement age band to between 55-62, while the after-retirement period to between ages 67-74. The estimated value for a is reported in the Appendix, in Table D.2.

---

[25]We take all the data from Table 2.4.5., "Personal Consumption Expenditures by Type of Product" of the Bureau of Economic Analysis.

[26]As noted earlier, precisely estimating the share of housing in the utility function is difficult for two reasons. First, the growth in housing services, which identifies α, is only non-zero for people who move house in that period. Second, our instrument set for housing growth is not very strong, which also implies that our estimates of α is imprecise.

[27]The normal retirement age is the age at which a person may first become entitled to full or unreduced retirement benefits. The normal retirement age is gradually increasing: in 1943 it was set to 66, while since 1960 it is 67.

Demographics. We take into account demographic changes within households over the life-cycle. Similar to the OECD equivalence scale, we use weight 1 for the first adult in the households, weight 0.7 for all the other adults in the households and weight 0.5 for each child under age 18.

Prices. All the variables in the model are expressed in 1982-1984 prices. We use consumer price index for nondurables with base-period 1982-1984 from the Federal Reserve Bank of St.Louis. The real interest rate in the model is set as the combination of the average real return on 3-month treasury bills and the risk-adjusted S&P returns, at an annual rate, $r = 0.025$.[28]

5.2   Parameters Estimated Within the Model

Once we have set the exogenous parameters which are invariant to the model solution, we have three remaining, key model parameters to set: the discount factor, β, the EIS parameter, and the degree of temptation, τ. We estimate these parameters using the full structural model. We set β, the EIS and τ to fit mean life-cycle profiles of nondurable consumption, liquid asset accumulation and housing asset accumulation between ages 25 and 60. Estimates of the parameter values are pinned down by choices over the levels of consumption and wealth accumulation. This is in contrast to the Euler approach where estimation uses variation in consumption growth in response to the interest rate and to changes in tempting resources.

We choose parameters to minimize the distance

$$d = \sum_m \sum_t \left[\frac{\text{moment}_{m,t}^{\text{model}} - \text{moment}_{m,t}^{\text{data}}}{\text{moment}_{m,t}^{\text{data}}} \right]^2 \tag{23}$$

between moments in the model and in the data. Moment$_{m,t}^{\text{model}}$ is moment m at age t from the simulated households, while moment$_{m,t}^{\text{data}}$ is the corresponding moment m at age t for the observed households in the CEX. For each age between 25 and 60, we target average nondurable consumption, liquid asset accumulation and housing asset accumulation. This gives a total of 108 moments.

We estimate β and the EIS parameter separately for the temptation and for the standard model. Results from this estimation are reported for both models in Table 7 below. Figure 1 shows the targeted and model-implied life-cycle profiles: the dotted lines

---

[28]According to Survey of Consumer Finance data, the share of stocks in households' financial assets is 26% on average. See Ameriks and Zeldes (2004) for example. Therefore, we calculate the return on liquid wealth by giving a weight of 0.26 to stock returns and a weight of 0.74 to bond returns. We use historical returns data between 1950 and 2010.

represent data from the CEX, the solid lines are profiles from the simulated temptation model, while the dashed lines are profiles from the simulated standard model.

Table 7: Estimated Parameters

	Temptation Model		Standard Model	
	MSM	Euler	MSM	Euler
	(1)	(2)	(3)	(4)
β	0.97		0.89	
	[0.96; 0.98]		[0.85; 0.93]	
E.I.S.	0.95	1.18	0.50	0.58
	[0.75; 1.15]	[0.44; 1.92]	[0.15; 0.85]	[-0.01; 1.18]
τ	0.28	0.22		
	[0.24; 0.32]	[0.02; 0.42]		

Note: Estimates of model parameters from the Euler equation and the Method of Simulated Moments for the temptation and the standard model. 95% confidence interval for the estimates are in parenthesis. Computation details of standard errors for the MSM estimates are in Appendix D.3

Model with Temptation

We first describe the performance of our baseline model, where temptation is allowed to play a role in individual preferences, and in the next subsection we compare it to the standard life-cycle model.

The value of β, EIS and τ are estimated to match liquid wealth, housing wealth, and consumption over the life-cycle and reported in the first column of Table 7. For ease of comparison, column two of Table 7 shows the estimated EIS and temptation parameters, from Section 4, together with their 95% confidence interval in square brackets.

The estimates of the EIS and τ are very similar to those estimated in the Euler equation, despite the source of identification being very different. The estimate of the EIS within the model is somewhat smaller, at 0.95, than what is obtained from the Euler equation, where it is 1.18. On the other hand, 0.95 is well within the 95% confidence interval of the Euler estimate. The value of τ equal to 0.28 within the model is very close to the Euler estimate of 0.22. These results show that our parameter estimates do

not vary substantially with the estimation method.[29] [30]

Figure 1 shows the life-cycle profiles of housing wealth, liquid wealth and consumption based on this parametrization of the temptation model (solid line), together with their empirical counterparts from the CEX (dotted line). To match the empirical moments, and in particular the accumulation of housing and liquid wealth, tempted households need to be patient and the estimated discount factor is relatively high. The temptation model generates liquid wealth and housing wealth that closely matches the profiles in the data. Households start saving early in life and keep their wealth primarily in housing, as in the data.

Figure 1: Simulated versus Targeted (CEX) Life-Cycle Profiles
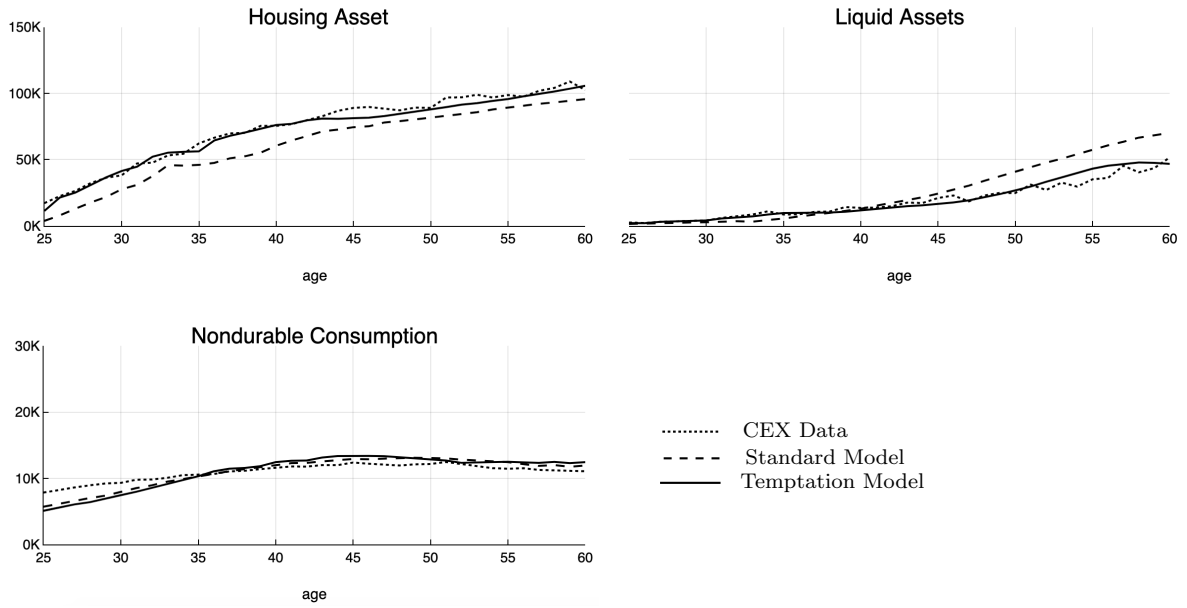
Note: The parameters for the temptation model are: $\beta = 0.97, \text{EIS} = 0.95, \tau = 0.28$.
The parameters for the standard model are: $\beta = 0.89, \text{EIS} = 0.50, \tau = 0$.

---

[29]There are various ways that the model can be extended, as discussed in section 2, which may affect estimates. For example, the model does not allow for bequests. We have experimented with mimicking a bequest motive through over-weighting utility at the point of death and reestimating the model. When consumption at the time of death is three times as valuable as usual, the value of the EIS needed to match the moments increases 0.95 to 1.28, the discount rate declines only marginally, and τ falls from 0.28 to 0.25. Interestingly, these estimates move the parameter estimates closer to the values from the Euler equation estimation (where the $EIS = 1.18$, and $\tau = 0.22$). We experimented with different weights on end-of-life utility, and the results are similar: bequests do not make a substantial difference to estimates of temptation. This arises because our estimate of the temptation parameter is pinned down by the share of liquid compared to illiquid wealth and this is not substantially affected by the presence of bequests.

[30]Further, we have assumed in our baseline that mortgages are not carried over into retirement. We test the importance of this assumption and re-estimated our model allowing individuals to hold mortgages up until the end of life. Our fit over ages 25-60 does not change and the estimated parameters are very similar to our baseline ($\beta = 0.97, E.I.S = 0.96, \tau = 0.27$).

The model matches the life-cycle profile of nondurable consumption from the CEX after age 35 well, while it underpredicts consumption somewhat at the beginning of the life-cycle. One problem with trying to match the level of consumption is that the model has only one type of consumption and all resources are spent on this consumption. By contrast, CEX data only measures nondurable consumption well. To map the model into the data on nondurable consumption, we need to make an assumption about what fraction of total consumption is nondurable consumption. In calculating the simulated moments, we assume this fraction is constant: independent of age and households' circumstances.[31]

Model Without Temptation

We contrast our baseline model of temptation with the standard life-cycle model. We report in column 3 of Table 7 the estimates of β and the EIS to match liquid wealth, housing wealth and consumption profiles while switching off the temptation parameter, τ, in the utility function. The life-cycle profiles based on this parametrization of the standard model are shown in Figure 1 (dashed line).

The EIS parameter estimated using the full model is 0.50, which is not significantly different from the estimate of 0.58 from using the Euler equation, as seen in the fourth column of Table 7. These values of the EIS are much lower than those obtained when allowing for temptation.

The estimated value of β is 0.895, which is lower than β in the temptation case. When β is low, individuals are impatient and want to bring consumption forward in time and not overaccumulate total wealth. Temptation and impatience are performing related functions: both preference parameters serve to increase current consumption and reduce wealth despite the economic incentives to defer consumption and save. The low value of β when we ignore temptation is similar to the values found in Cagetti (2003), who uses a standard life-cycle model and sets the impatience parameter to match wealth accumulation.

The problem with the simple life-cycle model is that it is unable to match simultaneously both liquid and housing wealth: households over-accumulate liquid wealth and under-accumulate housing. This can be seen in the first and second panels of Figure 1. Neither changing the EIS nor changing the discount rate can change the ratio of housing to liquid wealth while still matching the total amount of wealth accumulation. By contrast, in the temptation model, the parameter τ affects the ratio of housing to liquid

---

[31]When we estimate the EIS and temptation parameters in the Euler equation, identification comes from variation in the interest rate and variation in the amount of tempting resources, rather than from the rate of consumption growth per se. The average rate of consumption growth is captured by the constant of the Euler equation.

wealth because holding housing is a way to avoid the cost of temptation. Therefore the temptation model is able to match the large share of housing in total wealth, while still matching the level of total wealth. As with the temptation model, the standard model matches the life-cycle profile of nondurable consumption well only from age 35, while underpredicting consumption somewhat at the beginning of the life-cycle.

The Importance of Temptation

We estimate the temptation parameter τ to be 0.28 when estimating the full structural model and 0.22 when estimating the Euler equation. Our finding that temptation is important in explaining household decisions is consistent with experimental evidence from Toussaert (2018) showing that a substantial share of individuals suffer from temptation in the laboratory. That said, it is difficult to compare our point estimates to the experimental literature, as we estimate temptation in a dynamic rather than static setting.[32] More similar to our approach, Bucciol (2012) and Huang, Liu, and Zhu (2015) estimate the strength of temptation in a life-cycle framework and find evidence in support of temptation. Huang, Liu, and Zhu (2015) estimates $\tau = 0.19$ and Bucciol (2012) estimates $\tau = 0.05$.

The main difference between our approach and Bucciol (2012) is the definition of illiquid wealth. While we focus on housing, Bucciol (2012) focuses on retirement accounts, although in reality both might be important. This is a crucial distinction, as it affects the share of wealth held in illiquid form, which is the key aspect of the data that pins down the strength of temptation in our MSM approach and Bucciol's MSM approach. Our reading of the low estimate of the temptation parameter in Bucciol (2012) is that it is a consequence of the limited definition of illiquid wealth which excludes housing. In contrast, we find a higher temptation parameter due to the inclusion of housing in our definition of illiquid wealth, which results in a more realistic share of wealth held in illiquid form.[33]

---

[32]While there are very few papers that estimate the strength of temptation, there exists a much larger literature estimating the relevance of hyperbolic discounting.

[33]The definition of illiquid wealth has important implications for the share of wealth held in illiquid form. In Bucciol (2012), retirement accounts are assumed to be the only form of illiquid wealth, thus the share of illiquid wealth is very low, between 20% and 40% of total wealth depending on age. In contrast, in our approach where we focus on housing, the share of illiquid wealth is between 70% and 90%. The latter is closer to the share of illiquid wealth when both housing and retirement accounts are included. For instance, Angeletos et al. (2001) find a share of illiquid wealth that ranges between 76% and 92% depending on age. This finding is consistent with Kaplan and Violante (2014) and Gorea and Midrigan (2017) who highlight that housing, rather than retirement accounts, constitute the vast majority of households' illiquid wealth.

5.3 Implications: Housing as a Commitment Device

The source of the difference between the standard model and the temptation model is the additional value that housing brings in the presence of temptation. Transaction costs of housing imply that housing is less liquid than cash, and so housing serves as a commitment device. The extent that housing helps ease the temptation problem depends on the transaction cost. In this subsection, we show this implication of our model by varying the transaction cost, and contrast this with the effect of varying the transaction cost in the absence of temptation.

In our framework, an increase in transaction costs of housing (F) has two effects. First, a direct effect that makes housing less desirable compared to the liquid asset, given that housing cannot be used as easily for consumption smoothing purposes. Second, an indirect effect that increases the value of housing as a commitment device. Clearly, this indirect effect only plays a role when households have temptation preferences as standard households do not value commitment devices.

In Figure 2, we show the impact of varying the transaction cost on housing wealth. Our benchmark scenario, both for the temptation and the standard model, is when the transaction cost is 7% of the home's value $(F = 0.07)$ and the solid lines in Figure 2 show the implied housing demand. We then simulate housing demand with lower (dotted lines) and higher (dashed lines) transaction costs, setting F to be 0.05 and 0.15, respectively.[34]

Figure 2: The Effect of Fixed Cost on Housing Asset
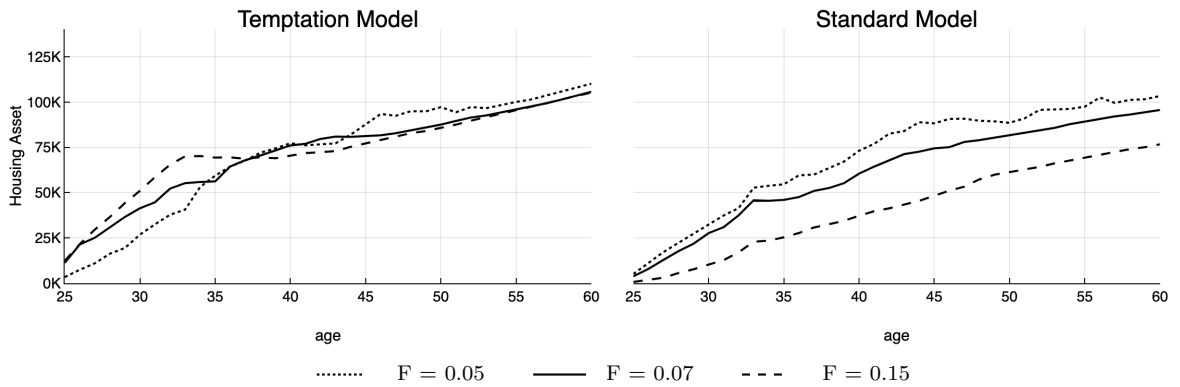
Note: The parameters for the temptation model and for the standard model are identical to those used in Figure 1.

Under temptation preferences, increasing transaction costs within this plausible range increases the demand for housing. The indirect effect that increases the value of housing

---

[34]Our benchmark temptation and standard models are estimated based on a 7% housing transaction cost $(F = 0.07)$. When we simulate the models with different values of F, we use the benchmark parametrization and only vary parameter F.

as a commitment device dominates the direct effect that makes housing less valuable for consumption smoothing. This is particularly striking in the first half of the life-cycle when housing wealth is substantially higher in situations where the transaction costs is higher.

The right-hand graph in Figure 2 shows that in the absence of temptation, increasing transaction costs leads to an unambiguous reduction in housing wealth. Under standard preferences, the direct effect of the transaction cost makes housing less useful for consumption smoothing. In contrast, the indirect effect disappears, as households do not value commitment.

Our estimated model with temptation preferences shows that housing is quantitatively important as a commitment device and that this has implications for how households respond to changes in the liquidity of housing. This mirrors the hypothesis first put forward by Strotz (1956), and also discussed in Laibson (1997) and recently in Kovacs and Moran (2019). Tempted households wish to hold most of their assets in housing, as its relative illiquidity allows them to decrease the cost of self-control. As a result, an important part of understanding housing demand is the demand for commitment devices.

6   Conclusion

In this paper, we estimate a structural life-cycle model of consumption and saving decisions, allowing us to evaluate the quantitative importance of temptation preferences proposed by Gul and Pesendorfer (2001).

We make three substantive contributions. First, we identify the importance of temptation by estimating the model-implied Euler equation on data from the Consumer Expenditure Survey. We find that the weight on the utility cost of temptation is about a quarter of the weight on the utility of consumption. Second, we show that estimating the Euler equation without controlling for the effect of temptation generates a serious omitted variable bias and leads to underestimation of the elasticity of intertemporal substitution (EIS). When we do not allow for temptation, we estimate the EIS parameter to be around 0.6. By contrast, when we include temptation, we obtain an EIS parameter of 1.2. Third, we demonstrate that allowing temptation to play a role means the model is able to simultaneously match the low levels of liquid wealth and high levels of housing wealth observed in the data. Without temptation, the best fit of the model leads to overaccumulation of liquid wealth and underaccumulation of housing wealth compared to the data.

The key conclusion of this paper is that allowing for temptation is crucial for under-

standing consumption smoothing behavior and illiquid asset accumulation over the life-cycle. Including temptation in life-cycle consumption decisions can have wide-ranging consequences, many of which we do not explore here. For example, Krusell, Kuruşçu, and Smith (2010) introduce temptation preferences into a macroeconomic setting with taxation. Nakajima (2012) evaluates the welfare consequences of rising household indebtedness in a model with temptation. Schlafmann (2016) studies the effects of temptation on housing and mortgage choices and the welfare consequences of mortgage regulations. Kovacs and Moran (2019) build on the framework in the current paper to show that temptation and commitment can account for the large share of hand-to-mouth households and generate realistic heterogeneity in the marginal propensity to consume. Further, Kovacs and Moran (2020) evaluate the costs and benefits of financial liberalisation that gives households greater access to home equity. All of these papers point to an ongoing agenda to reevaluate our understanding of households' life-cycle behavior.

A   Appendix to Section 2: Model Details

A.1   The Gul-Pesendorfer Framework

The main difference between the standard assumptions of dynamic decision theory and Gul and Pesendorfer's framework can be summarised as follows. According to the standard theory, preferences are defined over objects. Adding objects to a set cannot make the set less preferred. By contrast, in Gul-Pesendorfer's model, preferences are defined over sets of objects. Adding objects to a 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 consumer choice.

> *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 Betweenness): $A \succeq B$ implies $A \succeq A \cup B \succeq B$

The first three axioms are standard, but the last axiom, *Set Betweenness*, is the one that allows household to be tempted by the additional alternative in the set and to exercise self control. The fact that A is weakly preferred to $A \cup B$ 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. The fact that $A \cup B$ is weakly preferred to B indicates the possibility of self control.

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

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

when self-control is exercised and

$$U(A) := \max_{x \in A} u(x) \quad \text{subject to} \quad v(x) \geq v(y) \quad \text{for all} \quad y \in A$$

when no self-control is exercised. Here u represents long run/commitment utility over alternatives; v represents temptation utility over alternatives, so one can interpret $max_{y \in A} v(y) - v(x)$ as the utility cost of self control. In other words, one can think about alternatives as having two types of ranking, the commitment and the temptation ranking. When the household decides on which alternative she would like to consume, she takes a look at both rankings and maximises the possible utilities. After the decision, she enjoys the commitment and temptation utility of the alternative she did choose, but she suffers the loss of the temptation utility of the best alternative which she could have chosen as well.

A.2 Model Details

In the model, we control for the evolution of household composition over the life-cycle by using an exogenously given equivalence scale for each age, N_t. Therefore, correcting for household composition (3) becomes

$$
\begin{aligned}
u(C_t, S_t, N_t) &= N_t \frac{[(C_t/N_t)^\alpha (S_t/N_t)^{1-\alpha}]^{1-\rho}}{1-\rho} \\
&= N_t^\rho \frac{(C_t^\alpha S_t^{1-\alpha})^{1-\rho}}{1-\rho} \\
&= N_t^\rho u(C_t, S_t)
\end{aligned} \tag{A.1}
$$

For the ease of notiation, we disregard this exogenous shifter of the utility function in the main text.

B Appendix to Section 3: Empirical Strategy

B.1 Solution

In this section, we derive the Euler equation for the liquid asset, given that in the paper we only focus on estimating that optimality condition. The value function for the problem takes the following form

$$
\begin{aligned}
V_t(\Omega_t) &= \max_{C_t, H_{t+1}} \left\{ U(C_t, S_t, \tilde{C}_t) + \beta \mathbb{E}_t \left[V_{t+1}(\Omega_{t+1}) \right] \right\} \\
\Omega_t &= (A_t, Y_t, H_t, M_t)
\end{aligned} \tag{B.1}
$$

subject to the budget constraints

$$
A_{t+1} = R_{t+1} \begin{cases} A_t + Y_t - C_t - \mathbb{I}_{H_{t+1}=H_t}\mu_t - \mathbb{I}_{H_{t+1}\neq H_t}\left[(1+F)P_t(H_{t+1}) - \frac{M_{t+1}}{R^M}\right] \\[2ex] \qquad \text{if renter } (H_t = H^0) \\[3ex] A_t + Y_t - C_t - \mathbb{I}_{H_{t+1}=H^0}\mu_t - \mathbb{I}_{H_{t+1}=H_t}\xi_t \\[1ex] +\mathbb{I}_{H_{t+1}\neq H_t}\left[(1-F)P_t(H_t) - M_t - (1+F)P_t(H_{t+1}) + \frac{M_{t+1}}{R^M}\right] \\[2ex] \qquad \text{if homeowner } (H_t \neq H^0) \end{cases} \tag{B.2}
$$

The first order condition of the value function $V_t(\Omega_t)$ with respect to C_t is:

$$
\frac{\partial U_t(C_t, S_t, \tilde{C}_t)}{\partial C_t} = \beta \mathbb{E}_t\left[R_{t+1}\frac{\partial V_{t+1}(\Omega_{t+1})}{\partial A_{t+1}}\right] \tag{B.3}
$$

The envelope condition with respect to A_t is

$$
\frac{\partial V_t(\Omega_t)}{\partial A_t} = \frac{\partial U_t(C_t, S_t, \tilde{C}_t)}{\partial \tilde{C}_t} + \beta \mathbb{E}_t\left[R_{t+1}\frac{\partial V_{t+1}(\Omega_{t+1})}{\partial A_{t+1}}\right] \tag{B.4}
$$

Using equations (B.3) and (B.4) we get

$$
\frac{\partial V_t(\Omega_t)}{\partial A_t} = \frac{\partial U_t(C_t, S_t, \tilde{C}_t)}{\partial \tilde{C}_t} + \frac{\partial U_t(C_t, S_t, \tilde{C}_t)}{\partial C_t} \tag{B.5}
$$

Hence we can rewrite first order condition, (B.3), using (B.5) to have

$$
\frac{\partial U_t}{\partial C_t} = \beta \mathbb{E}_t\left[R_{t+1}\left(\frac{\partial U_{t+1}}{\partial \tilde{C}_{t+1}} + \frac{\partial U_{t+1}}{\partial C_{t+1}}\right)\right]
$$

Now using the utility function defined by equations (1) and (3):

$$
U_t(C_t, S_t, \tilde{C}_t) = \frac{(C_t^\alpha S_t^{1-\alpha})^{1-\rho}}{1-\rho} - \left[\lambda\frac{(\tilde{C}_t^\alpha S_t^{1-\alpha})^{1-\rho}}{1-\rho} - \lambda\frac{(C_t^\alpha S_t^{1-\alpha})^{1-\rho}}{1-\rho}\right]
$$

where

$$
\tilde{C}_t = \begin{cases} A_t + Y_t - \mu_t & \text{if renter } (H_t = H^0) \\[2ex] A_t + Y_t - \mu_t + (1-F)P_t(H_t) - M_t & \text{if homeowner } (H_t \neq H^0) \end{cases}
$$

$$
S_t \;=\; \begin{cases} \mu_t & \text{if } H_t = H^0 \\[2em] bP_t(H_t) & \text{if } H_t \neq H^0 \end{cases}
$$

We can derive the Euler equation for the liquid asset.

$$
(1+\lambda)\alpha\frac{(C_t^\alpha S_t^{1-\alpha})^{1-\rho}}{C_t} \;=\; \beta\mathbb{E}_t\left[R_{t+1}\left((1+\lambda)\alpha\frac{(C_{t+1}^\alpha S_{t+1}^{1-\alpha})^{1-\rho}}{C_{t+1}} - \lambda\alpha\frac{(\tilde{C}_{t+1}^\alpha S_{t+1}^{1-\alpha})^{1-\rho}}{\tilde{C}_{t+1}} \right) \right]
$$

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

B.2 Log-linearizing the Euler Equation for Liquid Asset

We express the Euler equation (13) in the following fashion

$$
1 = \mathbb{E}_t k_{t+1} R_{t+1}
$$

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

$$
k_{t+1} \;=\; \beta\frac{C_t}{(C_t^\alpha s_t^{1-\alpha})^{1-\rho}}\left(\frac{(C_{t+1}^\alpha S_{t+1}^{1-\alpha})^{1-\rho}}{C_{t+1}} - \tau\frac{(\tilde{C}_{t+1}^\alpha S_{t+1}^{1-\alpha})^{1-\rho}}{\tilde{C}_{t+1}} \right)
$$

In our case, the pricing kernel simplifies to

$$
\begin{aligned}
k_{t+1} \;&=\; \beta\frac{C_t}{C_{t+1}}\frac{(C_{t+1}^\alpha S_{t+1}^{1-\alpha})^{1-\rho}}{(C_t^\alpha S_t^{1-\alpha})^{1-\rho}}\left[1 - \tau\frac{C_{t+1}}{\tilde{C}_{t+1}}\frac{(\tilde{C}_{t+1}^\alpha S_{t+1}^{1-\alpha})^{1-\rho}}{(C_{t+1}^\alpha S_{t+1}^{1-\alpha})^{1-\rho}} \right] \\
&=\; \beta\left(\frac{C_{t+1}}{C_t}\right)^{-1+\alpha(1-\rho)}\left(\frac{S_{t+1}}{S_t}\right)^{(1-\alpha)(1-\rho)}\left[1 - \tau\left(\frac{\tilde{C}_{t+1}}{C_{t+1}}\right)^{-1+\alpha(1-\rho)} \right]
\end{aligned}
$$

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

$$k_{t+1} \;=\; \beta\Big(\frac{C_{t+1}}{C_t}\Big)^{-\kappa}\Big(\frac{S_{t+1}}{S_t}\Big)^{\kappa-\rho}\left[1 - \tau\Big(\frac{\tilde{C}_{t+1}}{C_{t+1}}\Big)^{-\kappa}\right]$$

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

$$
\begin{aligned}
\ln k_{t+1} \;=\;& \ln \beta - \kappa \ln\Big(\frac{C_{t+1}}{C_t}\Big) + (\kappa - \rho)\ln\Big(\frac{S_{t+1}}{S_t}\Big) \\
&+ \ln\left[1 - \tau\Big(\frac{\tilde{C}_{t+1}}{C_{t+1}}\Big)^{-\kappa}\right]
\end{aligned}
$$

Now taking the first order Taylor approximation around the steady state

$$
\begin{aligned}
\frac{1}{k}(k_{t+1} - k) \;=\;& \frac{1}{\beta}(\beta - \beta) - \kappa\left[\frac{C_{t+1}}{C_t} - 1\right] + (\kappa - \rho)\left[\frac{S_{t+1}}{S_t} - 1\right] \\
&+ \frac{\kappa\tau\big(\frac{\tilde{C}}{C}\big)^{-\kappa-1}}{1 - \tau\big(\frac{\tilde{C}}{C}\big)^{-\kappa}}\left[\frac{\tilde{C}}{C}\Big(\frac{\tilde{C}_{t+1}}{C_{t+1}} - \frac{\tilde{C}}{C}\Big)\right]
\end{aligned}
$$

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

$$\widehat{k}_{t+1} = -\kappa\widehat{\Big(\frac{C_{t+1}}{C_t}\Big)} + (\kappa - \rho)\widehat{\Big(\frac{S_{t+1}}{S_t}\Big)} + \kappa\frac{\tau\big(\frac{\tilde{C}}{C}\big)^{-\kappa}}{1 - \tau\big(\frac{\tilde{C}}{C}\big)^{-\kappa}}\widehat{\Big(\frac{\tilde{C}_{t+1}}{C_{t+1}}\Big)}$$

where we can use

$$\phi = \frac{\tau\big(\frac{\tilde{C}}{C}\big)^{-\kappa}}{1 - \tau\big(\frac{\tilde{C}}{C}\big)^{-\kappa}} = \frac{\tau}{\frac{1}{\big(\frac{\tilde{C}}{C}\big)^{-\kappa}} - \tau} = \frac{\tau}{\big(\frac{\tilde{C}}{C}\big)^{\kappa} - \tau}$$

So the log-linearized pricing kernel becomes

$$\widehat{k}_{t+1} = -\kappa\widehat{\Big(\frac{C_{t+1}}{C_t}\Big)} + (\kappa - \rho)\widehat{\Big(\frac{S_{t+1}}{S_t}\Big)} + \kappa\phi\widehat{\Big(\frac{\tilde{C}_{t+1}}{C_{t+1}}\Big)}$$

In what follows, we use the approximation:

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

$$
\begin{aligned}
\ln k_{t+1} - \ln k \;=\;& -\kappa \ln\left(\frac{C_{t+1}}{C_t}\right) + (\kappa - \rho)\ln\left(\frac{S_{t+1}}{S_t}\right) \\
&+ \;\kappa\phi\left[\ln\left(\frac{\tilde{C}_{t+1}}{C_{t+1}}\right) - \ln\left(\frac{\tilde{C}}{C}\right)\right] + \eta_{t+1}
\end{aligned}
$$

Now in the steady state

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

Substituting this steady state relationship into the previous equation

$$
\begin{aligned}
\ln k_{t+1} - \ln\beta - \ln\left[1 - \tau\left(\frac{\tilde{C}}{C}\right)^{-\kappa}\right] \;=\;& -\kappa\ln\left(\frac{C_{t+1}}{C_t}\right) + (\kappa - \rho)\ln\left(\frac{S_{t+1}}{S_t}\right) \\
&+ \;\kappa\phi\left[\ln\left(\frac{\tilde{C}_{t+1}}{C_{t+1}}\right) - \ln\left(\frac{\tilde{C}}{C}\right)\right] + \eta_{t+1} \quad\text{(B.6)}
\end{aligned}
$$

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

$$-\ln\left[1 - \tau\left(\frac{\tilde{C}}{C}\right)^{-\kappa}\right] = \ln\left[1 - \tau\left(\frac{\tilde{C}}{C}\right)^{-\kappa}\right]^{-1} = \ln\left(\frac{1}{1 - \tau\left(\frac{\tilde{C}}{C}\right)^{-\kappa}}\right)$$

Which equals $\ln(1 + \phi)$.

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

Now equation (B.6) can be rewritten

$$
\begin{aligned}
\ln k_{t+1} =\ & \ln \beta - \ln(1+\phi) - \kappa \ln \left(\frac{C_{t+1}}{C_t} \right) + (\kappa - \rho) \ln \left(\frac{S_{t+1}}{S_t} \right) \\
& + \ \kappa \phi \left[\ln \left(\frac{\tilde{C}_{t+1}}{C_{t+1}} \right) - \ln \left(\frac{\tilde{C}}{C} \right) \right] + \eta_{t+1}
\end{aligned}
$$

And the linearized Euler equation

$$
0 = \ln R_{t+1} + \mathbb{E}_t \ln k_{t+1}
$$

becomes

$$
\begin{aligned}
\kappa \ln \left(\frac{C_{t+1}}{C_t} \right) =\ & \ln \beta + \ln R_{t+1} - \ln(1+\phi) + (\kappa - \rho) \ln \left(\frac{S_{t+1}}{S_t} \right) \\
& + \ \kappa \phi \left[\ln \left(\frac{\tilde{C}_{t+1}}{C_{t+1}} \right) - \ln \left(\frac{\tilde{C}}{C} \right) \right] + \eta_{t+1}
\end{aligned} \tag{B.7}
$$

where η_{t+1} already contains expectation errors and deviations of second and higher moments from their unconditional means. Hence we can obtain an empirical version of the consumption Euler equation in the presence of temptation and housing in the utility function:

$$
\begin{aligned}
\ln \left(\frac{C_{t+1}}{C_t} \right) =\ & \frac{1}{\kappa} \ln \beta + \frac{1}{\kappa} \ln R_{t+1} - \frac{1}{\kappa} \ln(1+\phi) + \frac{\kappa - \rho}{\kappa} \ln \left(\frac{S_{t+1}}{S_t} \right) \\
& + \ \phi \ln \left(\frac{\tilde{C}_{t+1}}{C_{t+1}} \right) - \phi \ln \left(\frac{\tilde{C}}{C} \right) + \frac{1}{\kappa} \eta_{t+1}
\end{aligned}
$$

This equation can be further simplified to get equation (17), which we use in our estimation.

B.3   Quasi-Panel and Instruments

We create a quasi-panel by identifying groups or cohorts of households with similar characteristics of the household head and follow average values of the variables of interest for these homogenous groups over time as they age. Hence if there are N cohorts observed for T quarters, 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 B.1.

In the estimation we only use cohorts which have average cell size by quarter higher

than 200. This restriction is used in order to reduce the sampling noise. We also impose an age limit on the cohorts: we exclude observations for cohorts whose head on average is younger than 21 years or older than 60 years.

Table B.1: Cohort Definition

Cohort	Year of Birth	Age in 1994	Average Cell Size	Used in Estimation
	(1)	(2))	(3)	(4)
1	1975-79			no
2	1970-74	20-24	432	yes
3	1965-69	25-29	500	yes
4	1960-64	30-34	572	yes
5	1955-59	35-39	557	yes
6	1950-54	40-44	511	yes
7	1945-49	44-49	382	yes
8	1940-44	50-54	261	yes
9	1935-39	55-59	150	yes
10	1930-34			no

We use an instrumental variable estimation technique for several cohorts simultaneously.

In the situation where there is measurement error in the levels of variables, taking first differences creates an $MA(1)$ structure of the residuals in equation (20). But even without the presence of measurement error, taking first differences between the cohort means of different subsamples leads to an MA(1) process in the residuals.[35] Consequently and by the construction of the data, we always have to take account of the MA(1) error structure. Hence, the full residual in equation (20) 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, we conclude that the residuals are dominated by the MA(1) part. As a result, we cannot use one-period lagged variables as instruments, however instruments lagged two or more periods give consistent estimates. When aggregate variables such as the real interest rate or the inflation rate are used as instruments, they do not need to be lagged more than one period if the measurement errors in these variables are serially uncorrelated.

The panel dimension of CEX also implies that adjacent cells do not include completely different households. This fact also needs careful consideration for the following

---

[35]See Appendix C.2 for details on the effect of this on the variance-covariance matrix of residuals

reason. Households at their first interview in time period t appear also at time $t+1$, $t+2$ and $t+3$. Those at their fourth interview in time period t appear also at time $t-1$, $t-2$ and $t-3$. In the presence of household-specific fixed effects, we get inconsistent estimates if we use all the households both in the construction of the relevant variables and the instruments. Hence we follow Attanasio and Weber (1995) and manipulate the sample 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. we use all observations when we construct the variables entering our regression, but select subsamples when we construct the instruments. Specifically, in construction of lag 2 instruments, we use only households at the fourth interview, for lag 3 we only use households at the fourth and third interview and for lag 4 instruments, we 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 we estimate equation (20) 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.

C   Appendix to Section 4: Euler Equation Estimates

C.1   First-Stage Results

Table C.1: First Stages

	$\log(1+\text{r})$	$\Delta \log(S)$	$\log(\tilde{C}/C)$
	(1)	(2)	(3)
q1	-0.006***	-0.004	0.034*
	(0.001)	(0.009)	(0.019)
q2	-0.010***	-0.018**	0.033*
	(0.001)	(0.008)	(0.018)
q3	-0.003***	-0.029***	-0.022
	(0.001)	(0.008)	(0.018)
kids_growth	-0.007	0.375**	-0.434
	(0.018)	(0.161)	(0.338)
single_growth	0.020	-0.155	-0.445

	(0.016)	(0.144)	(0.302)
l.log(1+r)	1.465***	-5.478*	3.959
	(0.335)	(3.051)	(6.409)
l2.log(1+r)	-0.784**	5.506*	-1.083
	(0.352)	(3.212)	(6.746)
l2.famsize_growth	-0.001	0.014	-0.055**
	(0.001)	(0.012)	(0.026)
l3.famsize_growth	-0.002	-0.015	-0.014
	(0.003)	(0.023)	(0.049)
l3.$\Delta \log(Y)$	-0.009**	0.023	-0.341***
	(0.004)	(0.037)	(0.078)
l4.$\Delta \log(Y)$	0.000	-0.192***	-0.338***
	(0.005)	(0.047)	(0.099)
l2.$\Delta \log(S)$	0.001	-0.024	-0.034
	(0.003)	(0.023)	(0.048)
l3.$\log(S)$	0.004	-0.155***	-0.244***
	(0.005)	(0.043)	(0.090)
l2.$\log(\tilde{C}/C)$	-0.001	0.003	0.132***
	(0.002)	(0.019)	(0.039)
l3.$\log(\tilde{C}/C)$	0.000	0.004	0.505***
	(0.002)	(0.019)	(0.041)
l.shiller	-0.000**	0.002	0.008***
	(0.000)	(0.001)	(0.002)
l2.shiller	0.000	-0.001	-0.006***
	(0.000)	(0.001)	(0.002)
Constant	-0.023	1.062***	-2.649***
	(0.033)	(0.300)	(0.630)
F	16.578	3.132	197.661
Observations	274	274	274

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

C.2   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 we use in the paper is given by the following expression:

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

and the asymptotic variance-covariance matrix by:

$$\widehat{V}[\widehat{\beta}_{GMM}] = [\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X}]^{-1}[\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}S(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X}][\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X}]^{-1} \quad (C.2)$$

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 (20) 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

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

C.3 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 (20) with respect to the real interest rate.

$$
\frac{\partial \Delta \ln(C_{t+1})}{\partial r_{t+1}} \approx \theta_1 \frac{\partial \ln(1 + r_{t+1})}{\partial r_{t+1}} + \theta_2 \frac{\partial \Delta \ln(S_{t+1})}{\partial r_{t+1}} + \theta_3 \left(\frac{\partial \ln \tilde{C}_{t+1}}{\partial r_{t+1}} - \frac{\partial \ln C_{t+1}}{\partial r_{t+1}} \right) + \gamma' \frac{\partial \Delta Z_{t+1}}{\partial r_{t+1}}
$$

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 C.2 we 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 1.3. 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 10% in order to be able to match the data.
Recall

$$
\tilde{C}_{t+1} = A_{t+1} + Y_{t+1} + (1 - F)P_{t+1}(H_t) - M_t
$$

Now we write the unit house price, P_{t+1}, as the present discounted value of future stream of housing service in terms of consumption goods, assuming that the interest

Table C.2: Consumption Growth Componenets

	$\frac{\partial \Delta \ln(C_{t+1})}{\partial r_{t+1}}$	$\approx \theta_1 \frac{\partial \ln(1+r_{t+1})}{\partial r_{t+1}}$	$+\theta_3 \left(\frac{\partial \ln \tilde{C}_{t+1}}{\partial r_{t+1}} - \frac{\partial \ln C_{t+1}}{\partial r_{t+1}} \right)$
Standard	0.8%	$\approx 0.8 \cdot 1\%$	
Temptation	0.8%	$\approx 1.3 \cdot 1\%$	$+0.05 \cdot (-10\%)$

rate is persistent.

$$P_{t+1} = \sum_{j=0}^{\infty} \left(\frac{1}{1 + r_{t+1}} \right)^j bp \tag{C.3}$$

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, we 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

$$P_{t+1} = \frac{1 + r_{t+1}}{r_{t+1}} bp \tag{C.4}$$

D   Appendix to Section 5: Numerical Solution

D.1   Estimate for the Share of Nondurables

Table D.1: Estimates of α

Baseline (1)	Savings $\geq 1000\$$ (2)
0.481	0.564
(0.742)	(0.978)

D.2   Income Process

Table D.2: Estimated Income Process

	$\log y$
Age	0.283***
	(0.026)
Age^2/10	-0.049***
	(0.006)
Age^3/100	0.003***
	(0.000)
Constant	5.077***
	(0.343)
Observations	171
R-squared	0.86
Replacement rate	0.58

Note: Standard errors are in parenthesis.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

D.3   Standard Error Calculations for MSM Estimates

Based on the distance function in equation (23), the estimated structural parameters can be calculated as:

$$\widehat{\Xi} = \arg \min_{\Xi} \left(\widehat{m}^D - S^{-1} \sum_{s=1}^{S} \widehat{m}^S(\Xi) \right)' \Omega \left(\widehat{m}^D - S^{-1} \sum_{s=1}^{S} \widehat{m}^S(\Xi) \right)$$

where $\widehat{m}^D$ are the moments from the data, $\widehat{m}^S(\Xi)$ are the corresponding simulated moments (averaged over S simulations) for given structural parameter values Ξ. The function $m(\Xi)$ is the binding function relating the structural parameters to moments, and Ω is a weighting matrix. Our weighting matrix in the model is $\widehat{\Omega} = (\widehat{m}^D)^{-2}$, as seen from the distance function.

Standard errors of the structural parameters then can be computed by the following formula:

$$var(\widehat{\Xi}) = (J'\Omega J)^{-1} J'\Omega V \Omega J (J'\Omega J)^{-1}$$

where $J = \frac{\partial \widehat{m}^S(\Xi)}{\partial \Xi}$, and $V = var\left(\widehat{m}^D - \widehat{m}^S(\widehat{\Xi})\right)$. Assimptotically, V reduces to

$$(1 + \frac{1}{S})var\left(\widehat{m}^D\right)$$

, and we obtain $var\left(\widehat{m}^D\right)$ from data. We calculate J by finite difference.

50

D.4 Model Parameters

Table D.3: Annual Parameters for the Simulated Models

Parameter		*Value*	*Source*
T	*Number of years as adult*	60	
W	*Number of years as worker*	45	
Constant	*Age-specific income, constant*	5.077	Estimated: CEX
Age	*Age-specific income, linear trend*	0.283	Estimated: CEX
$Age^2/10$	*Age-specific income, quadratic trend*	-0.049	Estimated: CEX
$Age^3/100$	*Age-specific income, cubic trend*	0.003	Estimated: CEX
a	*Replacement rate*	0.58	Estimated: CEX
ρ	*Persistence of income shocks*	0.95	Estimated: CEX
σ_z	*Std.dev. of income shock*	0.2	Estimated: CEX
R	*Liquid asset return*	1.02	Fred
R^M	*Mortgage rate*	1.04	Fred
α	*Weight of durables in composite good*	0.82	BEA
b	*Housing service technology*	0.06	BEA
F	*Housing transaction cost*	0.07	
ψ	*Down-payment requirement*	0.2	
Temptation Model			
β	*Discount factor*	0.97	Estimated: MSM
EIS	*Elasticity of Intertemporal Substitution*	0.95	Estimated: CEX-MSM
τ	*Relative temptation*	0.28	Estimated: CEX-MSM
Standard Model			
β	*Discount factor*	0.89	Estimated: MSM
EIS	*Elasticity of Intertemporal Substitution*	0.50	Estimated: CEX-MSM

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