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MEASURING SELF-CONTROL PROBLEMS: A STRUCTURAL ESTIMATION

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Abstract

We adopt a two-stage Method of Simulated Moments to estimate the preference parameters in a life-cycle consumption-saving model augmented with temptation disutility. Our approach estimates the parameters from the comparison between simulated moments with empirical moments observed in the US Survey of Consumer Finances; to identify the parameters we consider moments from liquid and illiquid asset holdings at different ages. We find evidence of a small but significantly positive degree of temptation. The temptation model predicts consumption choices similar to the model with standard preferences, and holdings of liquid and illiquid assets closer to those observed in the empirical data. (JEL: D91, E21, G11)

1. Introduction

This paper assesses quantitatively a life-cycle consumption-saving model featuring temptation disutility as originally developed by Gul and Pesendorfer (2001). In the model, agents are rational, forward-looking, and sophisticated; they have time-consistent preferences, but their preferences are biased toward alternatives that offer more immediate gratification. This type of behavior is consistent with psychological theories (Della Vigna 2009) and has been observed empirically in different experiments (see Ameriks et al. 2007).

Although a number of authors have employed temptation disutility in various contexts—most noticeably asset pricing (Krusell, Kuruscu, and Smith 2002; DeJong and Ripoll 2007), addiction (Gul and Pesendorfer 2007), and social security (Kumru and Thanopoulos 2008)—an estimate of its parameters is currently missing. This paper attempts to bridge this gap by testing a variant of the model on survey data of asset

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holdings. We base our analysis on the framework of Gul and Pesendorfer (2004a), where the standard utility of consumption is augmented with the disutility of resisting the temptation to immediately consume all the available assets. Temptation utility incorporates one further preference parameter (the “degree of temptation”) that we may use to test for the presence of temptation on real data.

We identify the temptation motive by exploiting a feature of the model. Tempted agents want to hold their savings in commitment devices that will tie their hands and reduce exposure to tempting consumption alternatives. In particular, they may want to save in illiquid assets—in other words, assets that are not immediately accessible for withdrawal. A typical example is a retirement asset such as the 401(k) plan in the United States. Individuals usually invest in such plans rather than in liquid assets (accessible for withdrawal at any time) mainly because the plans offer tax incentives and the employee’s contributions are matched by the employer (see, e.g., Munnell, Sunden, and Taylor 2002; Choi et al. 2006). However, growing evidence suggests that investment is also driven by commitment reasons (Thaler and Benartzi 2004; Ashraf, Karlan, and Yin 2006). Gul and Pesendorfer (2004b) describe a simple three-period model of how temptation works in a setting with liquid and illiquid assets; in this paper, we use micro data to estimate the temptation motive from an extension of their model that features a life-cycle setting and a richer description of the illiquid asset.

The underlying model is a “buffer stock” model of life-cycle consumption and investment choices that accounts for uncertainty regarding labor income and mortality. The model is augmented with temptation disutility, as in Gul and Pesendorfer (2004a), and nests the standard utility without temptation as a special case. Agents choose how to allocate savings between liquid and illiquid assets; the illiquid asset limits the withdrawal of funds before retirement and has features similar to retirement plans (modeled as in Love 2006). We apply a two-stage method of simulated moments (MSM) approach (Pakes and Pollard 1989) to estimate structurally from survey data the parameters describing preferences in the life-cycle model (the degree of temptation, the rate of time preference, and the utility curvature parameter). This approach follows the literature on structural estimation of the preference parameters in life-cycle models, including the prominent works of Gourinchas and Parker (2002), Cagetti (2003), and Laibson, Repetto, and Tobacman (2009). Gourinchas and Parker (2002) and Cagetti (2003) use (respectively) age-specific consumption and wealth data to estimate the discount factor and the coefficient of relative risk aversion in a standard life-cycle model; Laibson, Repetto, and Tobacman (2009) use aggregate data on consumption, wealth, and credit card borrowing to estimate the preference parameters in a quasi-hyperbolic discounting model.

In this paper we perform a similar exercise using the temptation model. The MSM estimates the parameter values that lead the life-cycle model to predict the holdings of financial assets observed in the 1995–2007 waves of the US Survey of Consumer Finances. In the first stage of our MSM procedure, we calibrate the model’s exogenous parameters to describe the real US economy. In the second stage, we use this information to simulate many times the individual behavior predicted by the life-cycle model. We then estimate the preference parameters from the comparison between

simulated and target moments on age-specific liquid and illiquid asset holdings reported in survey data.

Our results can be summarized in three findings. First, in all our experiments, the estimated degree of temptation is small but significantly greater than zero. This suggests that the data are compatible with a temptation motive driving household behavior. Second, we find reasonable estimates of the remaining “standard” preference parameters in the model: we find a curvature parameter of 2.49 and a discount factor of 0.92, with small standard errors in both cases. In comparison, if we concentrate on the “restricted” standard model without temptation, then we estimate a curvature parameter (that coincides, in this case, with relative risk aversion) of 2.39, and a discount factor of 0.92. These values are in line with previous structural estimates, and they show that the preference parameters vary little when a degree of temptation is included in the utility function. Third, when we use the estimated preference parameters, the model augmented with temptation disutility predicts a consumption profile similar to the restricted model but predicts different holdings of liquid and illiquid assets. In particular, predicted holdings are closer to those observed in the real data. Although the temptation model does not explain life-cycle consumption and saving decisions better than does the restricted model, it may still be important in situations where the distinction between liquid and illiquid assets matters.

The paper is organized as follows. Section 2 introduces the theoretical model. Section 3 reviews the two-step MSM methodology for estimating the parameters in the model, and it briefly describes the target variables derived from survey data and the calibration of exogenous parameters (first-stage estimation). Also, Section 3 gives an illustrative example on the effect of changes in the preference parameters. Section 4 presents the MSM estimates of the parameters (second-stage estimation) prior to comparing the behavior predicted by the restricted and unrestricted models with the estimated preference parameters. The section ends with a robustness check of some critical parameters. Section 5 concludes, and the appendices provide mathematical details on the life-cycle model (Appendices A and B) and the computation of empirical values (Appendices C and D).

2. The Model

The economic framework consists of a life-cycle model in which time is discrete and t denotes adult age (effective age minus 24). Every period corresponds to one year, and an agent lives for a maximum of $T = 75$ periods: K as a worker and $T - K$ as a retiree. For the sake of simplicity, the retirement age K is taken to be exogenous. In the model we allow for uncertain mortality as in Hubbard et al. (1995); at any age t , individuals face a fixed probability π of surviving until the next period. Death is certain at age $T + 1$ (effective age 100).

The timing of the model is as follows. Agents start each period t with a given amount of assets; they then receive earnings and divide their consumption between nondurable goods and investment in illiquid assets. All variables are expressed in real terms.

2.1. Earnings

Following Zeldes (1989), income W_t^W at working age $t < K$ is exogenously described by a process featuring deterministic and random components. Thus, for $t = 1, \dots, K - 1$ and $P_0 = 1$ we have

$$\begin{aligned}\ln(W_t^W) &= \ln(P_t) + Z_t, \\ \ln(P_t) &= G_t^W + \ln(P_{t-1}) + N_t.\end{aligned}\quad (1)$$

Here G_t^W is a deterministic function of age and other individual characteristics, P_t is a permanent component with innovation N_t , and Z_t is a transitory component. The permanent shock N_t and the transitory shock Z_t are independent and identically normally distributed with mean 0 and respective variances σ_N^2 and σ_Z^2 . Income W_t^R at retirement age $t \geq K$ is described by a process that is limited to deterministic components:

$$\begin{aligned}\ln(W_t^R) &= \ln(P_t), \\ \ln(P_t) &= G_t^R + \ln(P_{t-1}).\end{aligned}\quad (2)$$

Here $t = K, \dots, T$ and G_t^R is a deterministic function of age and other individual characteristics.

An agent at working age t faces uncertain spells of unemployment, which are denoted by the dummy variable ω_t . The agent is employed when $\omega_t = 1$ and unemployed when $\omega_t = 0$; the age-dependent probability of being unemployed is $\theta_t > 0$. Earnings for an employed agent coincide with income, $Y_t = W_t^W$; earnings for an unemployed agent are a fraction of income, $Y_t = \xi W_t^W$ with $\xi \in (0, 1)$. Earnings at retirement are completely deterministic and coincide with income, $Y_t = W_t^R$.

2.2. Assets

Agents may hold liquid and illiquid financial assets. Liquid assets are personal savings invested in a portfolio of stocks, bonds, and safe assets. Illiquid assets are the savings accumulated in retirement plans and have the following features.

- Contributions are possible in any period before retirement age K .
- Contributions are matched by the employer.
- Contributions are tax deductible; that is, individuals can deduct the contributions from their earnings tax payment.
- Withdrawals from the account balance are always granted after retirement. Before retirement, they are granted only in the presence of unemployment spells ($\omega_t = 0$), in which case a penalty is paid.¹

1. In reality, early withdrawal is granted also under “special conditions” for hardship: the individual dies (in which case the money goes to a beneficiary); the individual is totally disabled; medical expenses accumulate to more than 7.5% of gross income; money is owed to a divorced spouse, or money is needed for home equity.

Both liquid and illiquid assets provide a gross return R ; however, because of employer matching and tax deductions, the effective return on illiquid assets is larger than that on liquid assets. In what follows we use A_t to denote the illiquid account consisting of all the savings in illiquid assets made up to year t , including their returns, and use S_t to denote the liquid account consisting of earnings in year t and all the savings in liquid assets made up to year t , including their returns. The liquid account thus includes all the wealth immediately available for consumption, or cash-on-hand.

Given S_t and A_t , the agent determines the optimal level of consumption, $C_t > 0$, as well as the contribution/withdrawal to/from the illiquid account, X_t . Here

$$\begin{aligned} X_t &\geq 0 & \text{if } t < K & \text{ and } \omega_t = 1; \\ X_t &< 0 & \text{if } t \geq K. \end{aligned} \quad (3)$$

Anything left after consumption and changes to the illiquid account is saved in the liquid account. The evolution of the *illiquid* account is given by

$$A_{t+1} = R(A_t + X_t + M_t), \quad A_{t+1} \geq 0. \quad (4)$$

Here M_t is the employer matching of contributions,

$$M_t = \max \{0, \mu \min \{X_t, \delta\}\}; \quad (5)$$

$\mu > 0$ is the match rate and $\delta > 0$ is the match limit. The evolution of the *liquid* account is given by

$$S_{t+1} = R(S_t - C_t - X_t + D_t + Q_t) + Y_{t+1}, \quad S_{t+1} \geq 0. \quad (6)$$

Here D_t and Q_t are (respectively) the tax deduction of contributions and the penalty for early withdrawals. For $\gamma > 0$ and $\kappa > 0$,

$$D_t = \gamma \max \{0, X_t\}; \quad (7)$$

$$Q_t = \begin{cases} \kappa \min \{0, X_t\} & \text{if } t < K, \\ 0 & \text{if } t \geq K. \end{cases} \quad (8)$$

When simulating profiles, we assume that households are born with an initial level of liquid and illiquid accounts, $S_0 \geq 0$ and $A_0 \geq 0$, whose values are jointly drawn from a multivariate log-normal distribution.

2.3. Preferences

Gul and Pesendorfer (2001) formalize the concepts of temptation and self-control while assuming that consumers have preferences not only over alternatives but also over *sets* of alternatives. For this purpose they formulate an axiom called “set betweenness” which, when combined with the usual axioms (completeness, transitivity, continuity, and independence), characterizes temptation preferences. Loosely speaking, under this axiom a consumer may prefer a given set of alternatives to another, larger set of

which the first is a subset. In other words, a consumer may want to tie her hands and eliminate from a set of alternatives those that are more tempting and costlier (in terms of self-control) not to choose. The axioms imply a representation of preferences in terms of two functions (see Gul and Pesendorfer 2001) that we include in the following instantaneous payoff function:

$$U(C_t, S_t) = u(C_t) - (v(S_t) - v(C_t)). \quad (9)$$

Here $u(\cdot)$ and $v(\cdot)$ are two von Neumann–Morgenstern utility functions, C_t denotes consumption at time t of nondurable goods, and cash-on-hand $S_t = \arg \max_{C_t} \{v(C_t)\}$ is the most tempting consumption alternative—that is, the largest consumption that is achievable in period t . This coincides with the illiquid account S_t because $C_t \leq S_t$ if the agent cannot die with debt and if mortality is uncertain. Agents' intertemporal preferences at time t are described by the following expected utility function:

$$U(C_t, S_t) + E_t \left[\sum_{k=t+1}^D (\beta\pi)^{k-t} (\pi U(C_k, S_k) + (1-\pi) B(S_k, A_k)) \right], \quad (10)$$

where β is the discount factor and $B(\cdot)$ is the utility from leaving a bequest.

For tractability, we follow Krusell, Kuruscu, and Smith (2002) and DeJong and Ripoll (2007) in characterizing $u(\cdot)$ as a constant relative risk aversion (CRRA) utility function,

$$u(C_t) = \frac{(C_t)^{1-\rho} - 1}{1-\rho}. \quad (11)$$

Here $\rho > 0$ is the curvature parameter, which coincides with the coefficient of relative risk aversion in standard settings without temptation. We also restrict our attention to a rescaled CRRA utility function for $v(\cdot)$,

$$v(C_t) = \lambda u(C_t); \quad (12)$$

where $\lambda \geq 0$, the *degree of temptation*, measures the agent's sensitivity to the tempting alternative. Note that preferences are of the standard CRRA type when $\lambda = 0$. The larger is λ , the more is the individual's behaviour controlled by temptation to consume, which in turn encourages agents to equalize consumption and cash-on-hand.² Finally, we follow the standard literature (e.g., Cagetti 2003) and assume that the function $B(\cdot)$ is a rescaled CRRA utility function of bequeathable wealth:

$$B(S_t, A_t) = \alpha u(S_t + A_t), \quad (13)$$

where the parameter $\alpha \geq 0$ reflects the degree of altruism. Our assumptions regarding the utility functions and the bequest function are useful for simplifying the solution method, since they allow us to drop earnings from the list of the problem's state variables.

2. The payoff function (9) with the specification in (11) and (12) is in line with the original theory of Gul and Pesendorfer (2001, 2004a) in that it makes tempted households risk averse in consumption but risk loving in cash-on-hand (since $-v(S_t)$ in (9) is convex). DeJong and Ripoll (2007) find that this specification of (9) is also consistent with balanced growth.

2.4. The Optimization Problem

We represent the agent's optimization problem using the recursive value function

$$V_t(S_t, A_t) = \max_{C_t, X_t} \{U(C_t, S_t) + \pi\beta E_t[V_{t+1}(S_{t+1}, A_{t+1}, P_{t+1})] + (1 - \pi)\beta E_t[B(S_{t+1}, A_{t+1}, P_{t+1})]\} \quad (14)$$

subject to constraints (1)–(13). The control variables of the problem are $\{C_t, X_t\}_{t=1}^T$, and the state variables are $\{t, S_t, A_t, P_t\}_{t=1}^T$. Following Carroll (1992), we standardize the variables via dividing by permanent income P_t and denote the standardized variables by lowercase letters (e.g., $c_t = C_t/P_t$). This allows us to reduce the dimensionality of the state space (see Appendix A for details). The problem does not admit a closed-form solution, so we derive the policy functions $c_t = c(s_t, a_t, t)$ and $x_t = x(s_t, a_t, t)$ numerically using backward induction.

At any age $t < T$, the optimizing behavior (disregarding corner solutions) is implicit in the following system of two equations (see Section A.2):

$$\begin{aligned} \frac{\partial U}{\partial c_t} &= \pi E_t \left[\beta_{t+1} R \left(\frac{\partial U}{\partial c_{t+1}} + \frac{\partial U}{\partial s_{t+1}} \right) \right] + (1 - \pi) E_t \left[\beta_{t+1} R \frac{\partial B}{\partial s_{t+1}} \right], \\ \frac{\partial U}{\partial c_t} &= \pi E_t \left[\beta_{t+1} R \frac{\partial U}{\partial c_{t+1}} \right] \\ &\quad + (1 - \pi) E_t \left[\beta_{t+1} R \frac{\partial B}{\partial a_{t+1}} \right] \left(\mathbf{1}_{\{x_t > 0\}} \left(\frac{1 + \mu}{1 - \gamma} \right) + (1 - \mathbf{1}_{\{x_t > 0\}}) \left(\frac{1}{1 - \kappa} \right) \right); \end{aligned} \quad (15)$$

where $\beta_{t+1} = \beta(P_{t+1}/P_t)^{-\rho}$. The two equations in (15) generalize the standard case when $\lambda = 0$. In particular, the first expression is the Euler equation for tempted agents. If we disregard the bequest motive, then the equation informs us 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 savings in the next period *minus* the marginal cost of resisting the additional temptation in the next period. Hence, ceteris paribus, the cost of saving is larger for tempted individuals than for non tempted ones.

Expectations in (15) are taken over earnings and employment uncertainty; for earnings we approximate integrals with the quadrature method described in Tauchen and Hussey (1991) while using a Gauss–Hermite quadrature of order nine. The solution is obtained via backward induction beginning with the last period T .

3. Estimation Method and Data

We adopt a two-stage MSM approach to estimate jointly the three preference parameters (λ, β, ρ) of the utility function (10) from the comparison between empirical and simulated moments.

In the first stage of our MSM procedure we set the exogenous parameters of the model, such as the asset rate of return and the earnings profile. We also measure

the uncertainty associated with this calibration. In the second stage we simulate life-cycle decisions from the model of Section 2, conditional on the exogenous and endogenous (preference) parameters. From the simulated behavior we derive values of liquid and illiquid asset holdings (“simulated” moments) that we then compare with their empirical counterparts from the Survey of Consumer Finances (“empirical” or “target” moments). The MSM procedure, which we shall describe in detail, determines the preference parameters that minimize the distance between simulated and empirical moments. The MSM is parsimonious in terms of input data, and it provides consistent estimates of the parameters without regard to specific functional form of the model’s equations (it is only the moments that matter). These features make this method ideal for studying behavior when long and reliable time series of wealth data are not available, and the underlying model is based on several crucial assumptions—for example, the choice of utility functions (11) and (12).

3.1. Method of Simulated Moments

Our structural estimation is based on the MSM developed by Pakes and Pollard (1989). The model described in Section 2 includes nuisance parameters χ that we treat as exogenous (e.g., the asset rate of return and the earnings profile) as well as J parameters θ that we consider to be endogenous (the preference parameters λ , β , and ρ). After making assumptions about the nuisance parameters, we numerically simulate the optimal behavior from a life-cycle model for a given set of endogenous parameters. We then estimate θ following a two-stage procedure similar to that used by Gourinchas and Parker (2002) and Laibson, Repetto, and Tobacman (2009). The method finds the estimate $\hat{\theta}$ that minimizes the distance between empirical (target) values and values simulated from the model. Section 3.2 provides details on the target values.

In the first stage, we calibrate the nuisance parameters χ with $\hat{\chi}$ to reflect characteristics of the US economy (see Section 3.2); the estimates $\hat{\chi}$ are associated with the covariance matrix $\hat{\Omega}_{\chi} = \text{var}(\hat{\chi})$. The second stage applies the MSM to estimate the unknown vector θ conditional on $\hat{\chi}$ and $\hat{\Omega}_{\chi}$. Let $\bar{m} = \sum_{i=1}^N m_i / N$ be a vector containing the average of the M target variables over the N empirical observations. Define the simulation analog to $\bar{m}$ by $\bar{m}(\theta, \chi) = \sum_{j=1}^S m_j(\theta, \chi) / S$, constructed as an average over S simulations. The moment condition implies that the expectation

$$E[g(\theta_0, \chi_0)] = E[\bar{m} - \bar{m}(\theta_0, \chi_0)] = 0,$$

where (θ_0, χ_0) is the true parameter vector. Let W be a positive-definite $M \times M$ weighting matrix, and define

$$q(\theta, \chi; W) = g(\theta, \chi)' W g(\theta, \chi) \quad (16)$$

as the (scalar) weighted sum of squared deviations of simulated moments from their corresponding empirical values. The MSM chooses θ to minimize the loss function

$q(\theta, \hat{\chi}; W)$.³

$$\hat{\theta} = \arg \min_{\theta} q(\theta, \hat{\chi}; W). \quad (17)$$

Pakes and Pollard (1989) show that, under some regularity conditions that are satisfied here, $\hat{\theta}$ is a consistent estimator of θ_0 and is asymptotically normally distributed with variance

$$\Omega_{\theta} = (G'_{\theta} W G_{\theta})^{-1} G'_{\theta} W \left(\Omega_g \left(1 + \frac{N}{S} \right) + G_{\chi} \Omega_{\chi} G'_{\chi} \right) W G_{\theta} (G'_{\theta} W G_{\theta})^{-1}, \quad (18)$$

where

$$G_{\theta} = \frac{\partial g(\theta_0, \chi_0)}{\partial \theta}, \quad G_{\chi} = \frac{\partial g(\theta_0, \chi_0)}{\partial \chi}; \quad (19)$$

$$\Omega_g = E[g(\theta_0, \chi_0) g(\theta_0, \chi_0)'], \quad \Omega_{\chi} = \text{var}(\chi). \quad (20)$$

In equation (18), $1 + N/S$ incorporates the correction for simulation error and $G_{\chi} \Omega_{\chi} G'_{\chi}$ the correction for first-stage uncertainty; failing to account for these two sources of uncertainty would significantly bias the standard errors (Gourinchas and Parker 2002; Laibson, Repetto, and Tobacman 2009). We use equation (18) to calculate standard errors for the estimates of θ , where all the matrices are estimated consistently from sample data (the variances $\hat{\Omega}_g$ and $\hat{\Omega}_{\chi}$) or from numerical analogs (the derivatives $\hat{G}_{\theta}$ and $\hat{G}_{\chi}$).

Two alternative weighting matrices are employed in our estimation. First, we choose a matrix that does not depend on the fitted model:

$$W_0 = (\hat{\Omega}_g)^{-1}. \quad (21)$$

This matrix (henceforth “robust”) is inherited from the generalized method of moments literature, and it is optimal when first-stage and simulation errors do not matter. Second, we employ the “optimal” weighting matrix

$$W_1 = \left(\hat{\Omega}_g \left(1 + \frac{N}{S} \right) + \hat{G}_{\chi} \hat{\Omega}_{\chi} \hat{G}'_{\chi} \right)^{-1}. \quad (22)$$

This matrix is efficient because it reduces the variance of the estimates to $(G'_{\theta} W_1 G_{\theta})^{-1}$. We estimate it using the consistent parameters obtained with the robust weighting matrix (21). A growing literature questions the small-sample validity of optimal weighting. Indeed, although the optimal weighting matrix can be more efficient than the robust weighting matrix, the former can also be more biased (see, e.g., Altonji and Segal 1996). In our analysis we therefore report the estimates obtained using both matrices (21) and (22).

If the model is correct then we can perform tests on overidentifying restrictions by using the statistic

$$\Xi(\hat{\theta}, \hat{\chi}) = g(\hat{\theta}, \hat{\chi})' W_1 g(\hat{\theta}, \hat{\chi}) \xrightarrow{d} \chi^2_{M-J}, \quad (23)$$

which coincides with the minimized function in (17) when $W = W_1$.

3. We perform the minimization with Matlab's Nelder–Mead simplex algorithm. This algorithm is slower but more robust than derivative-based methods.

3.2. *Targets and First-Stage Parameters*

The analysis conducted here applies to US households whose head has a high-school degree (and possibly some college education) but not a college degree. According to Stoops (2004), 57.4% of the US population aged over 24 have achieved this level of education.

The target moments are taken from five repeated cross sections (from 1995 to 2007) of the US Survey of Consumer Finances (SCF). In principle, we could use a variety of different target moments to estimate the preference parameters provided those moments capture the different commitment implications of the assets covered by the model. We concentrate on two types of target: the ratio of financial (liquid and illiquid) asset holdings to permanent income and the ratio of illiquid asset holdings to permanent income. It is not possible to identify the temptation parameter by using only one of these targets. Yet the combination of the two target types enables us to identify the effect of temptation by isolating the commitment motive; see Section 3.3 for further details.

Consistently with Gourinchas and Parker (2002) and Cagetti (2003), we consider targets that cover the entire working years and restrict our attention to 14 indicators that reflect the age profile of financial and illiquid asset holdings. Of these indicators, seven are ratios of financial (liquid and illiquid) asset holdings to permanent income (averages over the ages 28–32, 33–37, . . . , 58–62); the other seven are ratios of illiquid asset holdings to permanent income (averages over the same age ranges). We ignore older ages because we do not explicitly model health shocks. To derive our targets we take from the SCF the holdings in checking accounts, savings and money market accounts, call accounts at brokerages, certificates of deposits, savings bonds, corporate bonds, stocks, mutual funds, 401(k) accounts, IRA-KEOGH accounts, thrift and other retirement accounts, the cash value of life insurance policies, and other assets (in particular, annuities and trust-managed accounts). The sum of these assets corresponds to our definition of financial wealth, which we split into liquid and illiquid wealth. Consistently with the model, the definition of illiquid wealth includes only retirement accounts (namely: 401(k), IRA-KEOGH, thrift, and other retirement accounts). All remaining financial wealth is considered liquid. Appendix Section C provides details on the construction of the target moments, whose values are shown in Table 1.

The model also includes 26 exogenous parameters, described in Appendix D, that are calibrated as reported in Table 2. Observe that, in the table, not all the estimates are associated with a standard error. For ten of the parameters (the degree of altruism, the survival probability, the parameters on the features of the illiquid asset, and the parameters on unemployment) it is difficult to obtain an estimate, so we simply make an assumption and associate no standard error. As a result, the MSM standard errors depend on the uncertainty in the estimates of just 16 exogenous parameters. In Section 4.2 we check the robustness of our results to changes in the remaining ten parameters.

TABLE 1. Target moments.

Age group	Financial assets	Illiquid assets
28–32	0.5358 (0.0296)	0.1439 (0.0096)
33–37	0.6663 (0.0294)	0.2294 (0.0122)
38–42	0.8092 (0.0300)	0.3504 (0.0157)
43–47	0.9802 (0.0358)	0.5203 (0.0229)
48–52	1.2309 (0.0549)	0.7632 (0.0411)
53–57	1.6522 (0.0943)	1.1251 (0.0775)
58–62	2.4403 (0.1996)	1.6837 (0.1663)

Notes: Standard errors in parentheses.

Source: Authors' calculation from SCF data, 1995–2007 waves.

3.3. Illustrative Analysis

Gourinchas and Parker (2002) and Cagetti (2003) use the MSM to estimate the preference parameters of a standard life-cycle model from age-specific empirical moments on consumption and wealth levels, respectively. These authors disentangle the curvature parameter from the discount factor, exploiting the intertemporal substitution implicit in the slope of the empirical consumption–wealth profile.

In a model augmented with temptation disutility, such moments could not be used to identify the preference parameters. As an illustrative example, we now estimate the model's discount factor and curvature parameter conditional on a given degree of temptation. The parameters are obtained from the comparison between simulated⁴ and target moments, where the moments are statistics based on holdings of liquid asset only; our targets are the difference between the first and the second column of Table 1. From this analysis we obtain a discount factor $\beta = 0.8562$ and a curvature parameter $\rho = 2.2030$ while assuming $\lambda = 0$ (no temptation), $\beta = 0.8959$ and $\rho = 2.2558$ while assuming $\lambda = 0.10$, and $\beta = 0.9104$ and $\rho = 2.4003$ while assuming $\lambda = 0.20$. Figure 1 depicts the average liquid asset holdings over the working age simulated under these preferences; it shows that predictions from models with different combinations of (λ, β, ρ) are very close except for the ages near retirement (where the observed moments are less precisely estimated). In particular, different degrees of temptation are compatible with the observed holdings of liquid assets.

In general, agents have a desire to consume more and save less when they have weaker precautionary or retirement motives (governed by the discount factor and the curvature parameter) or when they have larger self-control costs (governed by the

4. We use the same 5,000 simulations of random variable realizations as in the main analysis.

TABLE 2. Calibration of the exogenous parameters (first-stage MSM).

Description	Symbol	Value	Std. error
Degree of altruism	α	0	—
Survival probability	π	0.9886	—
Retirement age	K	39	0.0377
Asset return	R	1.0344	0.0281
<i>Illiquid asset</i>			
Match rate	μ	0.5	—
Match limit	δ	0.06	—
Penalty rate	κ	0.1	—
Deduction rate	γ	0.2	—
<i>Income</i>			
Deterministic process, workers			
Constant	ψ_0^W	8.0886	0.4394
Age	ψ_1^W	0.1625	0.0323
Age ² /100	ψ_2^W	−0.2760	0.0775
Age ³ /10000	ψ_3^W	0.1569	0.0600
Family size	ψ_4^W	−0.0189	0.0041
Log(unemployment rate)	ψ_5^W	−0.1661	0.0519
Deterministic process, retirees			
Constant	ψ_0^R	9.9462	0.2909
Age	ψ_1^R	−0.0066	0.0026
Family size	ψ_2^R	0.0694	0.0376
Log(unemployment rate)	ψ_3^R	0.6405	0.1349
Permanent variance	σ_N^2	0.0277	0.0069
Transitory variance	σ_Z^2	0.0431	0.0129
Unemployment			
Replacement rate	ξ	0.10	—
Probability, age 25–34	θ_t	0.052	—
Probability, age 35–44	θ_t	0.043	—
Probability, age 45–62	θ_t	0.039	—
Initial values			
Financial assets	$S_0 + A_0$	0.3658	0.0341
Illiquid assets	A_0	0.0748	0.0404

degree of temptation). As a result, asset holdings fall with lower discount factors, lower curvature parameters, or higher degrees of temptation. Moreover, agents postpone the accumulation of savings to smooth their life-cycle consumption (because they have a higher elasticity of intertemporal substitution—that is, a lower curvature parameter) or when self-control costs are more severe (because the degree of temptation is higher). The temptation parameter then has an impact on both the size of savings (more tempted agents want to consume more and save less) and the slope of the savings age trend (more tempted agents want to delay saving to later years). However, the discount factor and the curvature parameter also control the asset size and slope. We can therefore find a combination of these two parameters that completely neutralizes the effect of a positive degree of temptation. The effect of temptation is then confounded in this setting.

FIGURE 1. Average simulated liquid asset holdings (illustrative analysis).

To disentangle the parameters of the model, the approach taken in this paper is to exploit information on both liquid and illiquid asset holdings at the same time. Thus the observed data reflect two effects of temptation. To limit their cost of self-control, tempted agents: (i) consume more, reducing and delaying the accumulation of savings; (ii) are inclined to save in illiquid assets, which provide commitment. Data on liquid assets reflect only the first effect, whereas data on illiquid assets reflect both. Figure 2 displays, over the working age and for the model with the preference parameters just described, the average illiquid asset holdings (panel A) and the average ratio of illiquid to total (liquid plus illiquid) asset holdings (panel B). The figure shows that such preference parameters—which generate similar liquid asset holdings—actually lead to markedly different behavior with respect to illiquid asset holdings: higher degrees of temptation predict larger holdings of illiquid assets (panel A) and larger ratios of illiquid to financial assets (panel B).

In this situation, all three preference parameters affect the accumulation of savings in both liquid and illiquid assets. However, the degree of temptation also influences the choice between liquid and illiquid assets; indeed, more tempted agents save relatively more in illiquid assets in order to commit their actions *against* tempting consumption alternatives. This allows us to disentangle the temptation effect from standard behavior. Hence, in the analysis that follows, we estimate the preference parameters from the

Figure 2. Average simulated illiquid asset holdings (illustrative analysis).

TABLE 3. Benchmark structural estimation, model without temptation.

	Estimate	S.E.(i)	S.E.(ii)	S.E.(iii)	S.E.(iv)
Robust weighting matrix					
λ	0	—	—	—	—
β	0.9058	(0.0068)	(0.0068)	(0.0000)	(0.0000)
ρ	2.4916	(0.0747)	(0.0747)	(0.0005)	(0.0004)
Test	63.89				
p -value	0.0000				
Optimal weighting matrix					
λ	0	—	—	—	—
β	0.9177	(0.0002)	(0.0002)	(0.0001)	(0.0001)
ρ	2.3928	(0.0027)	(0.0024)	(0.0020)	(0.0016)
Test	56.25				
p -value	0.0000				

Notes: S.E.(i), standard errors corrected for simulation error and first-stage uncertainty; S.E.(ii), standard errors corrected only for first-stage uncertainty; S.E.(iii), standard errors corrected only for simulation error; S.E.(iv), standard errors with no correction. The test is of the overidentifying restrictions and returns a p -value. The test follows a chi-squared distribution with twelve degrees of freedom, and its 5% critical value is 21.0261.

comparison between empirical and simulated data on illiquid *and* financial (liquid plus illiquid) asset holdings. Our strategy then chooses, among the infinite combinations of preference parameters that replicate the observed liquid asset holdings, the one that also predicts the observed illiquid asset holdings.

4. Results

In this section we report the MSM joint estimate of the three preference parameters in the temptation model (the degree of temptation, the discount factor, and the curvature parameter) using age-specific moments on financial and illiquid asset holdings. The analysis is based on $M = 5,000$ simulations over random realizations of initial asset holdings, earnings shocks, and age at death.

4.1. Benchmark Estimates

We start our analysis with the restricted model, in which the degree of temptation is set to zero ($\lambda = 0$); this case corresponds to the standard life-cycle model with CRRA preferences. In that environment, the MSM computes an estimate of only two parameters: the discount factor β and the curvature parameter ρ , which here coincides with relative risk aversion. Table 3 shows the output from this analysis; we obtain the point estimates $\beta = 0.9058$ and $\rho = 2.4916$ from using the robust weighting matrix (21) and the point estimates $\beta = 0.9177$ and $\rho = 2.3928$ from using the optimal weighting matrix (22). In both cases, the parameter estimates are within value ranges

that are considered plausible in the literature⁵ and are in line with previous structural estimates.⁶ The closest analysis to our framework is that of Cagetti (2003), who found a discount factor of $\beta = 0.917$ and a curvature parameter of $\rho = 4.45$ for high-school graduates by using mean financial wealth data from the SCF. Although we obtain nearly the same estimate of the discount factor, we estimate a much lower curvature parameter. In fact, our estimate falls between those given in Laibson, Repetto, and Tobacman (2009) and Cagetti (2003): 0.25 and 4.45, respectively. The reason is that our target moments share features with both works. Our moments distinguish between liquid and illiquid assets, as in Laibson, Repetto, and Tobacman (2009),⁷ and they inform on the age-specific asset profile, as in Cagetti (2003). Our estimate of the curvature parameter is higher than in Laibson, Repetto, and Tobacman (2009) to accommodate the empirical age-specific wealth profile, but it is lower than in Cagetti (2003) to reconcile predictions from the model with the data showing little savings placed in liquid assets.

The choice of weighting matrix does not seem to affect our point estimates. However, it does affect the standard errors, which are much smaller when we use the optimal weighting matrix. Table 3 also reports the standard errors computed using four different formulas. The measure reported as S.E.(i) incorporates corrections for the first-stage estimation and for the simulation error, as in equation (18). For comparison, we also report standard errors without these corrections: S.E.(ii) includes only the first-stage correction, S.E.(iii) includes only the simulation correction, and S.E.(iv) includes neither. Comparing the four measures reveals that the standard errors are marginally affected by the simulation error but greatly affected by the first-stage correction. In particular, it is this correction that produces dramatic changes when using either weighting matrix.

The test of overidentifying restrictions reported in the table (and labeled there as “Test”) follows from equation (23); it is a weighted sum of squared deviations of the simulated moments from their empirical analogs, where the weight is the optimal weighting matrix (22). The estimation method rejects the overidentifying restrictions at the 5% level. This is not surprising in view of the number of moments we use and the model’s few parameters. Similar conclusions are drawn in Gourinchas and Parker (2002) and Cagetti (2003).

Next we introduce the temptation model and allow the degree of temptation λ to vary. That is, the MSM now estimates the three preference parameters (λ, β, ρ)

5. The literature shows enormous variability in the estimates of the discount factor and the risk aversion parameter as a function of the framework (macroeconomic or microeconomic), the data (experimental or real decisions), the context (consumption decisions, saving decisions, etc.), and the units (students, working adults, retirees, etc.) under investigation. At a macroeconomic level, estimates generally take values between 0.88 and 0.96 for the discount factor (for a review, see Frederick, Loewenstein, and O’Donoghue 2002), and coefficients of relative risk aversion below 5 are usually considered to be acceptable (see Gollier 2004).

6. Among those works providing MSM structural estimates of the two parameters, the discount factor in comparable cases ranges between 0.91 (Laibson, Repetto, and Tobacman 2009) and 0.96 (Gourinchas and Parker 2002); the curvature parameter ranges between 0.28 (Laibson, Repetto, and Tobacman 2009) and 4.45 (Cagetti 2003).

7. The illiquid asset in Laibson, Repetto, and Tobacman (2009) is rather different from the one in this model, since it is meant to describe features of durable goods. In particular, agents are assumed only to buy and never to sell this asset, which also provides a fixed consumption flow in the utility function.

TABLE 4. Benchmark structural estimation (second-stage MSM).

	Estimate	S.E.(i)	S.E.(ii)	S.E.(iii)	S.E.(iv)
Robust weighting matrix					
λ	0.0521	(0.0055)	(0.0051)	(0.0034)	(0.0028)
β	0.9099	(0.0004)	(0.0004)	(0.0002)	(0.0002)
ρ	2.5639	(0.0136)	(0.0125)	(0.0094)	(0.0077)
Test	51.41				
p -value	0.0000				
Optimal weighting matrix					
λ	0.0565	(0.0031)	(0.0027)	(0.0028)	(0.0023)
β	0.9175	(0.0003)	(0.0003)	(0.0002)	(0.0002)
ρ	2.4853	(0.0087)	(0.0073)	(0.0082)	(0.0067)
Test	44.28				
p -value	0.0000				

Notes: S.E.(i), standard errors corrected for simulation error and first-stage uncertainty; S.E.(ii), standard errors corrected only for first-stage uncertainty; S.E.(iii), standard errors corrected only for simulation error; S.E.(iv), standard errors with no correction. The test is of the overidentifying restrictions and returns a p -value. The test follows a chi-squared distribution with eleven degrees of freedom, and its 5% critical value is 19.6751.

jointly. The output from this analysis is reported in Table 4; we estimate $\lambda = 0.0521$, $\beta = 0.9099$, and $\rho = 2.5639$ while using the robust weighting matrix and estimate $\lambda = 0.0565$, $\beta = 0.9175$, and $\rho = 2.4853$ while using the optimal weighting matrix. Here, too, the different weighting matrices give rise to similar point estimates that are, however, associated with sizably smaller standard errors in the latter case; in fact, standard errors shrink at least by one-fourth when we use the optimal weighting matrix. Since the estimates using either weighting matrix vary only marginally, in our discussion we concentrate on results obtained with the optimal weighting matrix.

Compared with the estimates derived from the restricted model (Table 3), the curvature parameter ρ is significantly larger whereas the discount factor β is not.⁸ With more curvature in the utility function, agents are more willing to save early in life for retirement and precautionary reasons. This effect is offset by a positive degree of temptation λ . Our estimate of this parameter, $\lambda = 0.0565$, is not far from the value that DeJong and Ripoll (2007) argue is necessary to explain some economic puzzles.⁹ Furthermore, the estimate is significantly different from zero ($0.0565 \div 0.0031 = 18.23$, which is much greater than 1.96). Since the standard model can be seen as a temptation model with $\lambda = 0$, this result rejects the standard model. Although the test of overidentifying restrictions still rejects the null hypothesis, it is about 21% lower than for the restricted model with $\lambda = 0$. The test can also be interpreted as a

8. By “significantly larger” we mean that the lower bound of the confidence interval for the curvature parameter in the temptation model, $2.4853 - 1.96(0.0087) = 2.4682$, is higher than the upper bound of the interval for the same parameter in the model without temptation, $2.3928 + 1.96(0.0027) = 2.3981$.

9. DeJong and Ripoll (2007) find that a degree of temptation of 0.0787 is necessary to reconcile the theory with data on stock price volatility, risk-free rates, and equity premiums.

FIGURE 3. Average simulated consumption profile (benchmark analysis).

goodness-of-fit measure, which suggests that the temptation model provides a fit—between simulated and empirical data—that is 21% closer than the fit provided by the restricted model.

Figure 3 shows the average consumption profile (up to retirement age) simulated from the temptation model and the restricted model. Both models generate a smooth, hump-shaped profile that is almost overlapped; consumption reaches its peak at around age 50 and then falls to accommodate the reduction in earnings after retirement. The two models generate similar predictions also in terms of asset moments. Figure 4 displays the average asset profile up to retirement age; panel A shows financial asset holdings and panel B shows illiquid asset holdings. The two panels also display the target moments and the corresponding moments simulated from the two models. We see that both models provide a close fit to the empirical data at young ages. The fit is poorer at older ages, where the target moments are estimated with less precision (see Table 1). Furthermore, the simulated holdings of illiquid assets are generally closer to the empirical ones than the holdings of financial assets, which are also estimated with less precision. Overall, the temptation model fits the data slightly better than the restricted model because it reduces the distance between empirical and simulated moments; the evidence of a small gain in terms of fit to the data is consistent with

FIGURE 4. Target and average simulated asset holdings (benchmark analysis).

TABLE 5. Sensitivity analysis: features of illiquid assets.

	Benchmark	Asset return		Penalty rate	
		$\mu = 0.25, \gamma = 0$	$\gamma = 0.3, \delta = 0.1$	$\kappa = 0.05$	$\kappa = 0.15$
λ	0.0565	0.0412	0.0512	0.0548	0.1079
S.E.	(0.0031)	(0.0041)	(0.0064)	(0.0036)	(0.0046)
β	0.9175	0.9365	0.9026	0.9238	0.9012
S.E.	(0.0003)	(0.0000)	(0.0008)	(0.0000)	(0.0004)
ρ	2.4853	2.8785	2.5101	2.5818	2.6068
S.E.	(0.0087)	(0.0141)	(0.0133)	(0.0112)	(0.0087)
Test	44.28	25.65	35.64	47.51	40.05
<i>p</i> -value	0.0000	0.0073	0.0002	0.0000	0.0000

Notes: Estimates use the optimal weighting matrix. Standard errors (S.E.) are corrected for simulation error and first-stage uncertainty. The test is of the overidentifying restrictions and returns a *p*-value. The test follows a chi-squared distribution with eleven degrees of freedom, and its 5% critical value is 19.6751.

previous findings in DeJong and Ripoll (2007) in an asset pricing context. Our findings suggest that the temptation model is not more useful than the restricted model for explaining life-cycle consumption–saving decisions, although it becomes relevant in situations where the focus is on the distinction between liquid and illiquid assets.

4.2. Sensitivity Analysis

The benchmark analysis discussed in Section 4.1 incorporates, in the optimal weighting matrix and the standard errors of the estimates, the first-stage correction for the uncertainty in most of the exogenous parameters. However, some first-stage parameters (e.g., the degree of altruism, the illiquid asset features) are difficult to pin down empirically, and for this reason they are merely set while assuming no uncertainty. In this section we explore the robustness of our findings to changes in such parameters. In what follows we report only the estimates in the temptation disutility model that result from using the optimal weighting matrix, and standard errors are corrected for simulation error and first-stage uncertainty. (Full results for all the cases are available upon request.)

We first concentrate our analysis on the parameters describing the features of the illiquid asset. Of the four parameters involved (the match rate μ , the match limit δ , the withdrawal penalty rate κ , and the deduction rate γ), three influence the effective rate of return on the illiquid asset and thereby alter the attractiveness of the illiquid asset relative to the liquid asset. In other words, all individuals, regardless of the degree of temptation, are willing to invest more in the asset when μ , δ , or γ increases. To test this claim, in the first part of Table 5 we report the results from a MSM estimate where the illiquid asset provides an effective return that is *lower* than in the benchmark case and closer to the liquid asset ($\mu = 0.25$, $\gamma = 0$) and also where the asset provides a *higher* effective return ($\gamma = 0.3$, $\delta = 0.1$). When the illiquid asset provides a lower return, agents must save more in order to achieve their target asset holdings. For this reason, estimates of the discount factor and the curvature parameter rise and the estimate of

TABLE 6. Sensitivity analysis: unemployment, bequest, and survival probability.

	Benchmark	Unemployment		Bequest $\alpha = 3$	Surv. prob $\pi = 0.9914$
		$\theta_t = 0.02$	$\xi = 0$		
λ	0.0565	0.0517	0.0583	0.0511	0.0664
S.E.	(0.0031)	(0.0081)	(0.0026)	(0.0046)	(0.0043)
β	0.9175	0.8953	0.9224	0.9289	0.9092
S.E.	(0.0003)	(0.0005)	(0.0003)	(0.0005)	(0.0004)
ρ	2.4853	2.7259	2.3538	2.8712	2.5426
S.E.	(0.0087)	(0.0221)	(0.0067)	(0.0093)	(0.0101)
Test	44.28	60.25	69.35	27.11	43.42
<i>p</i> -value	0.0000	0.0000	0.0000	0.0044	0.0000

Notes: Estimates use the optimal weighting matrix. Standard errors (S.E.) are corrected for simulation error and first-stage uncertainty. The test is of the overidentifying restrictions and returns a *p*-value. The test follows a chi-squared distribution with eleven degrees of freedom, and its 5% critical value is 19.6751.

the degree of temptation falls—although it is still significantly positive. The reverse is true in the other case, although then a significant change (a fall) in only the discount factor is enough to match the target variables.¹⁰

In contrast, the parameter κ directly affects the degree of liquidity of the retirement asset. A rise in the penalty rate κ creates larger commitment opportunities, which should make tempted agents willing to invest more in the illiquid asset. In the second part of Table 5 we report MSM estimates in which we assume lower and higher penalty rates than in the benchmark case ($\kappa = 0.05$ and $\kappa = 0.15$, respectively). In both cases, the preference parameters are precisely estimated; in particular, the degree of temptation λ is significantly positive and is about twice as large (nearly 11%) when the penalty rate increases. An increase in λ is needed to offset the willingness to invest more in illiquid assets, since agents with a higher degree of temptation are also willing to consume more. The other two parameters exhibit smaller changes with the penalty rate, and their adjustment is made to accommodate the variation in λ and to provide a match between empirical and simulated data.

A second set of exogenous parameters concerns unemployment. Love (2006) argues that individuals save in retirement assets also because such assets are a precautionary vehicle against employment risk. If this vehicle is weakened, then agents should be less willing to invest in illiquid assets. To investigate this possibility, in the first part of Table 6 we consider the cases $\theta_t = 0.02$ (i.e., unemployment probability of about half the benchmark probability) and $\xi = 0$ (no unemployment insurance). Our results suggest that the degree of temptation is unaffected by a change in these parameters, which induces variation in only the other two preference parameters. When the probability of unemployment is reduced ($\theta_t = 0.02$), there is less need for precautionary saving; the discount factor falls, and the curvature parameter rises

10. Indeed, the confidence interval of the discount factor ($0.9026 \pm 1.96(0.0008)$) does not include values from the confidence interval in the benchmark case ($0.9175 \pm 1.96(0.0003)$). This does not occur with the degree of temptation and the curvature parameter.

to match the target moments. In contrast, without unemployment insurance ($\xi = 0$), agents are less protected from unemployment spells and wish to accumulate more wealth for precautionary reasons; as a result, the discount factor rises and the curvature parameter falls to match the target moments.

We then consider a variation of the parameter governing the bequest utility. We set $\alpha = 3$ to reflect an 80% marginal propensity to consume cash-on-hand in the last period (when death is certain). That is, a person who is sure to die will leave 20% of her wealth to the heirs (as opposed to 0% when $\alpha = 0$). This requirement roughly follows the literature, where bequests are estimated to account for 15%–20% of total wealth (Modigliani 1988) and individuals with bequest motives are found to consume 25% less than individuals without bequest motives (see Kopczuk and Lupton (2007) and the literature reviewed there). Agents with a bequest motive receive utility from accumulating assets, which may be left to heirs once they pass away; this partially offsets the disutility of exerting self-control. However, in Table 6 we see that the effect of this calibration is negligible in our estimate of the degree of temptation, which remains at about 0.05; in contrast, estimates of the discount factor and the curvature parameter, rise significantly to reflect an increase in the propensity to save for a bequest motive.

We conclude our analysis with an estimate of the parameters following a rise in the survival probability. In this case, the coefficient is set to $\pi = 0.9914$ to produce an average life expectancy of 80 years; the associated MSM estimates are reported in the last column of Table 6. Although we find a significantly smaller discount factor and a significantly larger curvature parameter, there is no significant difference in the degree of temptation.

As a final remark, it is worth emphasizing that the estimate of the degree of temptation does not differ significantly from the benchmark case *unless* there is a change in the parameters of the illiquid assets. Even so, the estimate remains significantly positive; this suggests that the temptation model indeed provides a better fit to the data than the restricted model without temptation.

5. Concluding Remarks

In this paper we use a method of simulated moments approach to structurally estimate the three parameters describing preferences in a life-cycle model featuring temptation disutility. In this model, agents are tempted to consume all their assets in any given year; hence they seek to commit their actions by saving in illiquid assets and to eschew situations of exposure to more tempting alternatives. To identify the parameters of the model, we derive the target variables from survey data on liquid and illiquid (retirement) asset holdings.

We estimate a degree of temptation that is small but significantly different from zero. The temptation model predicts an intertemporal consumption profile similar to that of the restricted model without temptation, and temptation helps explain the observed holding of illiquid assets relative to liquid assets.

There are several directions for further research. Future work should enrich the realism of the underlying model—for instance, by relaxing the assumption of homogeneous preferences and dividing the population into groups of tempted and nontempted agents. Another important direction for future research is the inclusion in the model of other relevant forms of nonliquid savings (in particular, housing) that may influence portfolio decisions. However, such analysis would be complicated because housing is used for both consumption and commitment reasons. Finally, it may be instructive to compare predictions from the temptation model with those from alternative models that also feature preference for commitment. In particular, the well-known quasi-hyperbolic discounting model finds that commitment is valuable because agents have time-inconsistent preferences (see Laibson 1997). Using a simple three-period setting, Kocherlakota (2001) concludes that this model is unable to predict simultaneous holdings of liquid and illiquid assets. It is not clear whether extending the quasi-hyperbolic discounting model to include many periods and a richer characterization of the illiquid assets would be enough for it to yield more realistic conclusions.

Appendix A: Reducing the Dimensionality of the State Space

To reduce the dimensionality of the state space, we standardize the variables by dividing by permanent income P_t . A clear link emerges between value functions based on nonstandardized (uppercase letters) and standardized (lowercase letters) variables. Let us denote by C_t^* and X_t^* , respectively, the optimal consumption and investment choices made in period t ; as before, we use lowercase letters for any variable that (in period t) is divided by permanent income P_t . At terminal age $t = T$,

$$\begin{aligned} V_T(S_T, A_T, P_T) &= U(C_T^*, S_T) + \pi E_T [\beta B(S_{T+1}, A_{T+1}, P_{T+1})] \\ &= (P_T)^{1-\rho} U(c_T^*, s_T) + \pi E_T [\beta (P_{T+1})^{1-\rho} B(s_{T+1}, a_{T+1})] \\ &= (P_T)^{1-\rho} \left(U(c_T^*, s_T) + \pi E_T \left[\beta \left(\frac{P_{T+1}}{P_T} \right)^{1-\rho} B(s_{T+1}, a_{T+1}) \right] \right) \\ &= (P_T)^{1-\rho} V_T(s_T, a_T) \end{aligned} \quad (\text{A.1})$$

under specifications (9)–(13) of the utility functions. At age $t = T - 1$,

$$\begin{aligned} V_{T-1}(S_{T-1}, A_{T-1}, P_{T-1}) &= (P_{T-1})^{1-\rho} \left(U(c_{T-1}^*, s_{T-1}) \right. \\ &\quad \left. + \pi E_{T-1} \left[\beta \left(\frac{P_{T-1}}{P_T} \right)^{1-\rho} V_T(s_T, a_T) \right] \right. \\ &\quad \left. + (1 - \pi) E_{T-1} \left[\beta \left(\frac{P_{T-1}}{P_T} \right)^{1-\rho} B_T(s_T, a_T) \right] \right) \\ &= (P_{T-1})^{1-\rho} V_{T-1}(s_{T-1}, a_{T-1}). \end{aligned} \quad (\text{A.2})$$

The dynamic budget constraints (4) and (6) can be rewritten as

$$\begin{aligned} a_T &\leq R(a_{T-1} + x_{T-1} + m_{T-1}) \frac{P_{T-1}}{P_T}, \\ s_T &\leq R(s_{T-1} - c_{T-1}^* - x_{T-1}^* + d_{T-1}^* + q_{T-1}^*) \frac{P_{T-1}}{P_T} + y_T. \end{aligned} \quad (\text{A.3})$$

It can be shown that the following identity holds at a generic time t :

$$V_t(S_t, A_t, P_t) = (P_t)^{1-\rho} V_t(s_t, a_t), \quad (\text{A.4})$$

where

$$\begin{aligned} V_t(s_t, a_t) &= U(c_t^*, s_t, a_t) \\ &\quad + \pi E_t [\beta_{t+1}^* V_{t+1}(s_{t+1}, a_{t+1})] + (1 - \pi) E_t [\beta_{t+1}^* B(s_{t+1}, a_{t+1})] \end{aligned} \quad (\text{A.5})$$

subject to the budget constraints

$$\begin{aligned} a_{t+1} &\leq R(a_t + x_t + m_t) \frac{P_t}{P_{t+1}}, \\ s_{t+1} &\leq R(s_t - c_t^* - x_t^* + d_t^* + q_t^*) \frac{P_t}{P_{t+1}} + y_{t+1}, \end{aligned} \quad (\text{A.6})$$

and where

$$\beta_{t+1}^* = \beta \left(\frac{P_{t+1}}{P_t} \right)^{1-\rho}. \quad (\text{A.7})$$

Because $V_t(S_t, A_t, P_t)$ and $V_t(s_t, a_t)$ differ by only a scale factor (see equation (A.4)), it follows that – from the agent's perspective – obtaining the optimal consumption and investment choices from the maximization of either function is equivalent.

Appendix B: Solution to the Life-Cycle Problem

To derive the system of equations (15), we compute the first-order condition of $V_t(s_t, a_t)$ with respect to c_t ,

$$\begin{aligned} \frac{\partial V_t(s_t, a_t)}{\partial c_t} &= 0 \Rightarrow \\ \frac{\partial U(c_t, s_t)}{\partial c_t} &= \pi E_t \left[\beta_{t+1} R \frac{\partial V_{t+1}(s_{t+1}, a_{t+1})}{\partial s_{t+1}} \right] \\ &\quad + (1 - \pi) E_t \left[\beta_{t+1} R \frac{\partial B(s_{t+1}, a_{t+1})}{\partial s_{t+1}} \right], \end{aligned} \quad (\text{B.1})$$

and with respect to x_t :

$$\begin{aligned} \frac{\partial V_t(s_t, a_t)}{\partial x_t} &= 0 \Rightarrow \\ (1 - \gamma) E_t \left[\pi R \frac{\partial V_{t+1}(s_{t+1}, a_{t+1})}{\partial s_{t+1}} + (1 - \pi) R \frac{\partial B(s_{t+1}, a_{t+1})}{\partial s_{t+1}} \right] \\ &= (1 + \mu) E_t \left[\pi R \frac{\partial V_{t+1}(s_{t+1}, a_{t+1})}{\partial a_{t+1}} + (1 - \pi) R \frac{\partial B(s_{t+1}, a_{t+1})}{\partial a_{t+1}} \right] \end{aligned} \quad (\text{B.2})$$

if $x_t \geq 0$ or

$$\begin{aligned} & (1 - \kappa) E_t \left[\pi R \frac{\partial V_{t+1}(s_{t+1}, a_{t+1})}{\partial s_{t+1}} + (1 - \pi) R \frac{\partial B(s_{t+1}, a_{t+1})}{\partial s_{t+1}} \right] \\ &= E_t \left[\pi R \frac{\partial V_{t+1}(s_{t+1}, a_{t+1})}{\partial a_{t+1}} + (1 - \pi) R \frac{\partial B(s_{t+1}, a_{t+1})}{\partial a_{t+1}} \right] \end{aligned} \quad (\text{B.3})$$

if $x_t < 0$. We then use the envelope theorem and derive $V_t(s_t, a_t)$ with respect to s_t ,

$$\begin{aligned} \frac{\partial V_t(s_t, a_t)}{\partial s_t} &= \frac{\partial U(c_t, s_t)}{\partial s_t} + \pi E_t \left[\beta_{t+1} R \frac{\partial V_{t+1}(s_{t+1}, a_{t+1})}{\partial s_{t+1}} \right] \\ &+ (1 - \pi) E_t \left[\beta_{t+1} R \frac{\partial B(s_{t+1}, a_{t+1})}{\partial a_{t+1}} \right], \end{aligned} \quad (\text{B.4})$$

and with respect to a_t ,

$$\begin{aligned} \frac{\partial V_t(s_t, a_t)}{\partial a_t} &= \pi E_t \left[\beta_{t+1} R \frac{\partial V_{t+1}(s_{t+1}, a_{t+1})}{\partial a_{t+1}} \right] \\ &+ (1 - \pi) E_t \left[\beta_{t+1} R \frac{\partial B(s_{t+1}, a_{t+1})}{\partial a_{t+1}} \right]. \end{aligned} \quad (\text{B.5})$$

Using (B.1) and (B.4), we find that

$$\frac{\partial V_t(s_t, a_t)}{\partial s_t} = \frac{\partial U(c_t, s_t)}{\partial c_t} + \frac{\partial U(c_t, s_t)}{\partial s_t}. \quad (\text{B.6})$$

Furthermore, plugging (B.1) and (B.5) into (B.2) and (B.3) yields

$$\frac{\partial V_t(s_t, a_t)}{\partial a_t} = \frac{1 - \gamma}{1 + \mu} \frac{\partial U(c_t, s_t)}{\partial c_t} \quad (\text{B.7})$$

if $x_t \geq 0$, or

$$\frac{\partial V_t(s_t, a_t)}{\partial a_t} = (1 - \kappa) \frac{\partial U(c_t, s_t)}{\partial c_t} \quad (\text{B.8})$$

if $x_t < 0$. Hence we can use (B.6)–(B.8) to rewrite the first-order conditions as follows:

$$\begin{aligned} \frac{\partial U(c_t, s_t)}{\partial c_t} &= \pi E_t \left[\beta_{t+1} R \left(\frac{\partial U(c_{t+1}, s_{t+1})}{\partial c_{t+1}} + \frac{\partial U(c_{t+1}, s_{t+1})}{\partial s_{t+1}} \right) \right] \\ &+ (1 - \pi) E_t \left[\beta_{t+1} R \frac{\partial B(s_{t+1}, a_{t+1})}{\partial s_{t+1}} \right] \end{aligned} \quad (\text{B.9})$$

and

$$\begin{aligned} \frac{\partial U(c_t, s_t)}{\partial c_t} &= \pi E_t \left[\beta_{t+1} R \frac{\partial U(c_{t+1}, s_{t+1})}{\partial c_{t+1}} \right] \\ &+ (1 - \pi) \left(\frac{1 + \mu}{1 - \gamma} \right) E_t \left[\beta_{t+1} R \frac{\partial B(s_{t+1}, a_{t+1})}{\partial a_{t+1}} \right] \end{aligned} \quad (\text{B.10})$$

if $x_t \geq 0$, whereas

$$\begin{aligned} \frac{\partial U(c_t, s_t)}{\partial c_t} &= \pi E_t \left[\beta_{t+1} R \frac{\partial U(c_{t+1}, s_{t+1})}{\partial c_{t+1}} \right] \\ &+ (1 - \pi) \left(\frac{1}{1 - \kappa} \right) E_t \left[\beta_{t+1} R \frac{\partial B(s_{t+1}, a_{t+1})}{\partial a_{t+1}} \right] \end{aligned} \quad (\text{B.11})$$

if $x_t < 0$.

Appendix C: Details on the Target Moments

The target moments are taken from repeated cross-sections of the US Survey of Consumer Finances. The SCF collects detailed information on assets and liabilities for a sample of US households; the data used here are exceptionally good for our purpose because the survey (i) uses a sample specifically designed to support wealth estimation and (ii) handles missing data by computing five complete data sets of imputed values. We focus on the waves from 1995 to 2007 (five waves) to disentangle age, year, and cohort effects in the construction of each target variable. From the waves we collect data on socio-demographic characteristics, normal income,¹¹ and financial assets. We exclude nonfinancial assets such as housing because their accumulation is driven also by reasons that we do not model explicitly (e.g., the decision to buy or sell a house may be related to changes in the household size).

From this data set we consider a homogeneous subsample based on households whose head is male, is married,¹² has a high school degree, and earns a strictly positive normal income. The definition of financial assets includes checking accounts, savings accounts, money market accounts, call accounts at brokerages, certificates of deposit, saving bonds, corporate bonds, stocks, mutual funds, 401(k) accounts, IRA-KEOGH accounts, thrift and other retirement accounts, life insurance (in cash value), and other assets (including, e.g., trusts, annuities, and loans from the household). The sum of holdings in all these assets determines our measure of financial wealth. To compute illiquid wealth we sum only the 401(k), IRA-KEOGH, thrift, and other retirement accounts; then the difference between financial wealth and illiquid wealth is what we call liquid wealth.

We derive the target moments as predictions from a bivariate ordinary least-squares regression. For each household in the sample whose head is not retired and is of age 24 to 62,¹³ we compute the ratios of financial and illiquid asset holdings over normal income, where normal income serves as a proxy for permanent income.¹⁴ We set the logarithms of these two ratios as dependent variables in the model, whose specification includes the family size and a cubic polynomial on age. Our data set covers a relatively broad range of years featuring varied economic and institutional circumstances. In particular, because retirement assets were not widespread before 1983 (see Holden, Brady, and Hadley 2006 for a history of 401(k) plans), it is likely that households in the least recent waves accumulated less wealth in illiquid assets than did households in the most recent waves. To capture this effect, we include in the specification the number

11. The survey defines normal income as an income that is not “unusually high or low compared to what [a household] would expect in a ‘normal’ year”. This information is not available in waves before 1995, which we ignore for that reason.

12. We ignore households consisting of single heads because asset-based welfare programs may influence the savings decisions of singles (Hubbard, Skinner, and Zeldes 1995), in ways that we do not model explicitly.

13. Age 62 corresponds to the median *last* working age in the SCF sample; see Appendix D.

14. We could not consider assets and income separately—and then use the ratio of means to construct the target moments—because assets are strongly skewed to the right. For instance, the ratio of mean to median for financial (respectively, illiquid) assets is 4.44 (9.72), whereas for income this ratio is only 1.21.

of years of enrollment in the main retirement asset in the household's portfolio. To control for cohort and year effects, we also include five-year dummies for the birth year and the logarithm of the unemployment rate (source: US Bureau of Labor Statistics).¹⁵ The empirical specification for the generic i th household is then

$$\begin{aligned}\tilde{w}_i &= \varphi_0^w + size_i \varphi_1^w + age_i \varphi_2^w + \frac{age_i^2}{100} \varphi_3^w + \frac{age_i^3}{10,000} \varphi_4^w + ten_i \varphi_5^w + lunemp_i \varphi_6^w \\ &\quad + cool_1 \varphi_7^w + \dots + cool_5 \varphi_{10}^w + cool_7 \varphi_{11}^w + \dots + cool_{11} \varphi_{15}^w + \varepsilon_i^w, \\ \tilde{a}_i &= \varphi_0^a + size_i \varphi_1^a + age_i \varphi_2^a + \frac{age_i^2}{100} \varphi_3^a + \frac{age_i^3}{10,000} \varphi_4^a + ten_i \varphi_5^a + lunemp_i \varphi_6^a \\ &\quad + cool_1 \varphi_7^a + \dots + cool_5 \varphi_{10}^a + cool_7 \varphi_{11}^a + \dots + cool_{11} \varphi_{15}^a + \varepsilon_i^a. \quad (C.1)\end{aligned}$$

Here $\tilde{w}_i$ and $\tilde{a}_i$ are the logarithms of the ratios of asset holdings (financial and illiquid, respectively) to normal income; the parameters φ^w and φ^a are to be estimated; $size_i$ is the family size; $lunemp_i$ is the logarithm of the unemployment rate; age_i , $age_i^2/100$, and $age_i^3/10,000$ are the cubic polynomial on age; ten_i is the tenure in years of enrollment in the retirement asset, $cool_1, \dots, cool_5, cool_7, \dots, cool_{11}$ is a complete set of cohort dummies (except for the middle cohort, 1956–1960); and $(\varepsilon_i^w, \varepsilon_i^a)$ are residuals that capture measurement error and all the remaining individual effects. The regression accounts for multiple imputations and sampling weights, and it is based on 2,484 genuine observations.

Given the estimates from this regression, for each age between 24 and 62 we derive the asset holding of a “typical” household with a regular tenure of illiquid assets while excluding cohort and year effects. Thus:

$$\begin{aligned}\hat{w}_{age} &= \hat{\varphi}_0^w + \overline{size}_{age} \hat{\varphi}_1^w + age \hat{\varphi}_2^w + \frac{age^2}{100} \hat{\varphi}_3^w + \frac{age^3}{10,000} \hat{\varphi}_4^w \\ &\quad + (age - 24) \hat{\varphi}_5^w + \overline{lunemp}_{age} \hat{\varphi}_6^w, \\ \hat{a}_{age} &= \hat{\varphi}_0^a + \overline{size}_{age} \hat{\varphi}_1^a + age \hat{\varphi}_2^a + \frac{age^2}{100} \hat{\varphi}_3^a + \frac{age^3}{10,000} \hat{\varphi}_4^a \\ &\quad + (age - 24) \hat{\varphi}_5^a + \overline{lunemp}_{age} \hat{\varphi}_6^a.\end{aligned} \quad (C.2)$$

Here $\overline{size}_{age}$ and $\overline{lunemp}_{age}$ are (respectively) the average age-dependent family size and log-unemployment rate from the sample, and $(age - 24)$ describes a typical tenure since the beginning of adult age. Note that, with the specification in (C.2), the typical household is the one with head born in the middle cohort of our sample, 1956–1960. We then construct average age profiles of asset holdings by averaging these data across

15. In this we follow the prevailing empirical literature (e.g., Gourinchas and Parker 2002). Observe that, with this specification, assets have a time-invariant age profile; hence cohort and year effects have an impact only on the distance between the assets of different cohorts.

groups of five consecutive years (28–32, 33–37, . . . , 58–62):

$$\begin{aligned}\hat{w}_{\overline{age}} &= \frac{1}{5} (\hat{w}_{age-2} + \hat{w}_{age-1} + \hat{w}_{age} + \hat{w}_{age+1} + \hat{w}_{age+2}), \\ \hat{a}_{\overline{age}} &= \frac{1}{5} (\hat{a}_{age-2} + \hat{a}_{age-1} + \hat{a}_{age} + \hat{a}_{age+1} + \hat{a}_{age+2}).\end{aligned}\quad (C.3)$$

Table 1 reports the target moments in our sample together with their standard errors. The latter are computed from standard errors and covariances of the regression parameters in equation (C.2). The estimate of total financial assets around retirement, 2.4403, is in line with values found in comparable studies (e.g., Laibson, Repetto, and Tobacman 2009). According to our estimates, households tend to hold a ratio of illiquid to financial assets that increases steadily with age and ranges from 20.44% to 68.99%. We use the standard errors in the table to estimate the moments' covariance matrix Ω_g .

Appendix D: Details on the First-Stage Parameters

The model includes 26 exogenous parameters whose benchmark calibration is reported in Table 2. The degree of altruism is set to $\alpha = 0$ in order to generate a 100% marginal propensity of consumption in the last year of life, $t = D$ (when death is certain). This implies that all bequests are accidental and generated by an uncertain lifespan (as suggested by Hurd 1989). We take as a conditional survival probability the value $\pi = 0.9886$, which ensures a life expectancy (at the beginning of working age) of 50 years and hence up to age 75—consistently with current figures for males from various sources (e.g., the US Social Security Administration; see Bell and Miller 2005). Retirement is set at age $K = 39$ (effective age 63). This number, in line with Laibson, Repetto, and Tobacman (2009) and median figures in Munnell, Soto, and Golub-Sass (2008), is the median retirement age reported in the data set that we use to compute the target moments (a subsample of the 1995–2007 waves of the SCF; see Appendix C), and is associated with a standard error of 0.0377 in the sample. For the asset returns, we consider an average of $R = 1.034$ with standard deviation 0.03, following Gourinchas and Parker (2002); the authors compute it as the average real return on Moody's AAA municipal bonds over the period from January 1980 to March 1993.

We then set the four parameters describing the features of the illiquid assets to match features of a typical 401(k) plan. Following the calibration in Love (2006), we assume an employee's match rate to be $\mu = 0.5$ with a match limit of $\delta = 0.06$. That is, the employer matches 50 cents for each dollar contributed by the employee, with the match ending when employee contributions equal 6% of compensation. We also set a penalty rate before retirement of $\kappa = 0.1$ as well as a deduction rate of $\gamma = 0.2$ that resembles the effective federal tax rate (see Congressional Budget Office 2007). The assumption of positive deduction rates and match rates gives rise to an effective return to illiquid assets that exceeds the return to liquid assets, as frequently documented in the literature (Brennan and Subrahmanyam 1996; Pàstor and Stambaugh 2003).

We estimate income profiles from the same SCF subsample that we used to derive the target moments. Household income follows a broad definition, much as in Cocco, Gomes, and Maenhout (2005), that implicitly allows for (potentially endogenous) ways of self-ensuring against pure labor income risk. The definition includes wages, self-employment and business income, social security, and pension income; it excludes unemployment insurance because we separate it from trend income.

After converting household income to 2000 USD,¹⁶ we restrict the sample to households whose head is not younger than 25 and declares to be either employed or retired. We estimate separately two regressions, one for workers and one for retirees. The estimation model assumes that log-income $\log(Y_i) = y_i$ is a linear function of family size, an age polynomial of degree three for workers and degree one for retirees, the log-unemployment rate (as a proxy for year-specific business cycle effects), and birth year:

$$y_i = \begin{cases} \psi_0^W + size_i \psi_1^W + age_i \psi_2^W + \frac{age_i^2}{100} \psi_3^W + \frac{age_i^3}{10,000} \psi_4^W + lunemp_i \psi_5^W \\ \quad + coo1_i \psi_6^W + \dots + coo5_i \psi_{10}^W + coo7_i \psi_{11}^W + \dots + coo11_i \psi_{15}^W + \varepsilon_i^W, & age_i < K; \\ \psi_0^R + size_i \psi_1^R + age_i \psi_2^R + lunemp_i \psi_3^R \\ \quad + coo1_i \psi_4^R + \dots + coo5_i \psi_8^R + coo7_i \psi_9^R + \dots + coo11_i \psi_{13}^R + \varepsilon_i^R, & age_i \geq K. \end{cases} \quad (D.1)$$

Here the variables are the same as those described in Appendix C. Table 2 displays the coefficient estimates and standard errors for this regression, where each observation is weighted using the weight provided in each wave of the survey. The results are in line with income regressions estimated in the literature (e.g., Cocco, Gomes, and Maenhout 2005). We use these estimates to compute, for each age, the log-income prediction (uncontaminated by cohort and year effects) for a household of typical age-dependent family size $\overline{size}_{age}$, facing the average log-unemployment rate $\overline{lunemp}_{age}$, and whose head has born in the middle cohort (as in Appendix C):

$$\hat{y}_{age} = \begin{cases} \hat{\psi}_0^W + \overline{size}_{age} \hat{\psi}_1^W + age \hat{\psi}_2^W + \frac{age^2}{100} \hat{\psi}_3^W + \frac{age^3}{10,000} \hat{\psi}_4^W \\ \quad + \overline{lunemp}_{age} \hat{\psi}_5^W & age < K \\ \hat{\psi}_0^R + \overline{size}_{age} \hat{\psi}_1^R + age \hat{\psi}_2^R + \overline{lunemp}_{age} \hat{\psi}_3^R & age \geq K. \end{cases} \quad (D.2)$$

16. Using the seasonally adjusted consumer price index (CPI) for all urban consumers, all items. Source: US Federal Reserve.

We then derive the income growth rate as

$$\hat{G}_t = 1 + \hat{y}_t - \hat{y}_{t-1}. \quad (\text{D.3})$$

The variances of permanent and transitory shocks are set to $\sigma_N^2 = 0.0277$ and $\sigma_Z^2 = 0.0431$, respectively; these values are based on Carroll and Samwick (1997), who use the Panel Study of Income Dynamics data on before-tax labor earnings. (The same values are used also in Gourinchas and Parker 2002.) Following the benchmark parameters for high-school graduates in Love (2006), we set to $\xi = 0.10$ the replacement rate for the employed and set θ_t , the age-dependent probability of being unemployed, to 0.052 for $t \in [25, 34]$, to 0.043 for $t \in [35, 44]$, and to 0.039 for $t \in [45, 62]$. Love (2006) derives these probabilities from data on job displacement. Observe that, according to this calibration, the probability of being unemployed decreases with age.

Finally, we derive the initial levels of the target variables (financial and illiquid asset holdings) by following the approach described in Appendix C. We calculate the predictions in age 24 (the year before the start of adult age in our model) from equation (C.2); their standard errors are computed from standard errors and covariances of the regression parameters in equation (C.2). In the simulations, we draw initial values for liquid and illiquid asset holdings jointly from a multivariate, log-normal distribution with average value and standard deviation reported in Table 2 and with a correlation of 40.03% obtained from the same data.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix: Data sets and programs used for the analysis in sections 3.4 and 4 of the paper (zip file)

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