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Savings decisions under life-time and earnings uncertainty: Empirical evidence from West German household data*

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Abstract: We analyze a model of life-cycle savings decisions which allows for both life-time and income uncertainty. We then simulate life-cycle saving rates based on empirical income processes estimated from West German household data. Our main findings are, first, that allowing for mortality risk improves the life-cycle model's predictions slightly, and second, that simulated saving rates still fail to match their empirical counterparts. While our model correctly predicts differential peak saving rates during working life for three household types that face different income processes, it cannot explain an important salient feature of saving in Germany: Empirically, there is almost no post-retirement dissaving, while our life-cycle model predicts substantial dissaving even though we control for the generous German pension system which results in relatively high post-retirement income.

Keywords: savings, life-cycle models, income uncertainty, life-time uncertainty

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1 Introduction

A key element of household behavior, saving, is still not satisfactorily understood. The seminal life-cycle theory of saving by Ando, Modigliani and Brumberg (e. g., Modigliani and Brumberg (1954)) has been augmented with features such as liquidity constraints, mortality, income risk and other uncertainties, and, more recently, by behavioral elements. While each of these extensions explains some part of saving behavior, empirical contradictions remain widespread, especially when looking at household data (see Browning and Lusardi (1996) for an overview).

In this paper, we contribute to this literature by adding a new combination of extensions to the standard life-cycle model. Specifically, our model combines liquidity constraints and both life-time and income uncertainty. Neither of these features is new to the literature, of course. Liquidity constraints have been considered by, *inter alia*, Deaton (1991). Life-time uncertainty has first been analyzed by Yaari (1965) in a model of life-insurance demand. Skinner (1985) introduced uncertainty about the time of death in a life-cycle optimization framework, and Hurd (1989) analyzed the effect of life-time uncertainty on bequests. In Skinner's model, which is closest to the one we analyze below, life-time uncertainty is the only source of uncertainty while both the interest rate and the income processes are assumed to be known with certainty. Models with a fixed planning horizon (i. e., certain time of death) and income uncertainty have been discussed extensively in the literature (for example, Zeldes (1989a), Carroll (1992, 1997) and Hochguertel (1998)). The way in which we combine these features is new, to the best of our knowledge. Moreover, we test whether the fact that households differ in the degree of income risk they face matters for life-cycle saving decisions. We do this by considering three types of occupation that are likely to involve different degrees of income risk.

The empirical strategy of this paper is standard: We simulate savings decisions over the entire life cycle using a numerical solution of the underlying intertemporal optimization problem, taking the income process as given. However, we do not use fixed growth rates in the deterministic income component, but use empirical age-income profiles, an issue to which we return shortly. We then compare our simulated age-savings profiles with empirical age-savings profiles for West German households. The dataset we use is a large pseudo-panel that consists of four waves covering the 1978–1993 period, the *Einkommens- und Verbrauchsstichprobe* (EVS), a datset that is roughly comparable to the U.S. Consumer Expenditure Survey (CEX).

One important feature of our simulation analysis is that we calibrate income processes for three household types that differ both in their life-cycle income profiles and in income risk. In addition to the average household, we also consider households whose heads are civil servants (who are subject to relatively modest degrees of income risk) and self-employed (who face higher income risk than the average household). It is well known that in models with precautionary or buffer-stock saving, a higher variance of labor income should increase saving.

There is a growing literature that tries to test this implication by analyzing the effects of past income variance on current wealth. Skinner (1988) uses occupation dummies in an approach that is closest to ours in sprit: we also compare saving rates across different occupation groups. However, Skinner's findings are in contrast to those we report below; he finds that savings of people with riskier incomes are lower. Carroll and Samwick (1997, 1998) estimate income variances from panel data and then regress the level of wealth on these variances, finding that wealth is systematically higher for consumers with higher income variability. A number of studies use panel data from Italy to assess the effects of income variability. These include Guiso *et al.* (1992, 1996), Lusardi (1997) and Pistaferri (1998). A common conclusion from these studies is that income uncertainty indeed increases savings and/or wealth. An important advantage of the Italian panel which these authors use is that it contains subjective measures for expected income variability; this allows to avoid some identification problems associated with the estimation of income variances and the use of occupation dummies.[1] Finally, Gakidis (1997) estimates a portfolio choice model for 1984 using PSID data, in which income dynamics enter via parameters estimated over the 1974–1984 period from the same panel. He also finds that "the stochastic properties of labor income have a substantial effect on stock-holding behavior".

Because of the limitations of our dataset, we cannot estimate the parameters of a fully specified income process. Instead, we calibrate the parameters of the income process such that they reflect relative differences in income risk between the household types we consider. The deterministic component of the income profiles, i. e., the income growth rates, are then taken to match their empirical counterparts. In our view, this is an improvement over related simulations studies in which the deterministic component of income growth is assumed to be constant over the active working life.[2]

By taking this approach to simulating life-cycle savings profiles, we implicitly assume that the income process experienced by households is exogenous with respect to savings and other life-cycle decisions; this assumption is standard in this literature. It implies, however, that we abstract from labor supply decisions which would be part of a richer model of a household's life-cycle behavior. In such a model, the income process is endogenous with respect to savings and other life-cycle decisions such as labor supply and

[1] For example, Guiso *et al.* (1996) argue that "occupational dummies may capture labor supply effects that have little to do with risk" (p. 162). Lusardi (1997) also concludes that occupation dummies might be a bad proxy for income variance in wealth regressions.

[2] In an empirical analysis of the determinants of wage growth among young workers in Germany, Dustmann and Meghir (1998) stress the fact that understanding the determinants of wage growth is important in empirical life-cycle models. With our data, we cannot explore the determinants of individual wage growth, but at least we allow wage growth to vary over time.

retirement.[3] We note from the outset that simulating savings profiles derived from such a more realistic model of life-cycle behavior has to be left for future research.

The remainder of this paper is structured as follows. We report empirical income and savings profiles for West Germany in Section 2. In Section 3, we present a version of the standard life-cycle model of savings decisions which allows for both life-time and income uncertainty. We calibrate this model to match German household data, solve it numerically and compare simulated saving rates with their empirical counterparts in Section 4. Section 5 concludes.

2 Empirical income and savings profiles for West Germany

The empirical life-cycle savings and labor earnings profiles which we present in this section are based on German household data taken from the 1978, 1983, 1988 and 1993 waves of the *Einkommens- und Verbrauchsstichprobe* (EVS). The EVS is the German equivalent of the U.S. Consumer Expenditure Survey (CEX). However, the EVS is not a panel, rather, it consists of repeated cross-sections based on quinquennial surveys conducted by the Federal Statistical Office. Currently, the 1993 wave is available as a public use file to researchers; data from earlier waves can be obtained under certain restrictions.

The two measures we use in this paper are household net income (specifically, net labor and transfer income, i. e., disposable income *excluding* interest on current wealth), and total savings, defined as the residual of total household income and total expenditures in a given period. Details of the construction of our income and savings measures can be found in the Data Appendix. In what follows, we use pooled data taken from all four waves, measured in 1991 prices (unless noted otherwise).

As noted before, we consider two types of households which are supposed to differ from the "average household" in the degree of income risk they face. Hence, our benchmark is the average of all households, referred to simply as the group of *all households* in the sequel. The subset of households whose head is a *civil servant* is taken to represent low-risk income households, and the sub-set of households whose head is *self employed* is taken to face a high degree of income risk.

Figure 1 shows age-income profiles for the three occupation groups. One can see that these groups start with rather different average levels of net income at the age of 20. Also, the life-cycle profiles are remarkably different, with the peak of net income at 43 years for all households, 45 years for the self employed, and at 52 years for the civil servants. After the age of 60, we only report income and savings profiles for the average household because

[3] For example, Houser (1998) presents a dynamic, stochastic model of labor supply and savings decisions that exhibits such features. His primary interest is on labor supply, however. Rust (1990) describes a model of decisions at the end of the life cycle that also allows for both labor supply and savings decisions. His main interest is the timing of the retirement decision.

the income growth rates and saving rates do not differ very much for retired households while measurement problems become increasingly serious after retirement for a number of reasons. Together with the fact that the variances of the income processes are likely to differ accross these groups as well (an issue to which we return below), the differences of the age-income profiles shown here suggest that it is important to distinguish household types when analyzing life-cycle savings decisions.

Next, we show empirical savings profiles. Figure 2 depicts total household savings in levels for the three occupuation groups. It does not come as a surprise that savings are much higher for the self employed than for the average household, given that most of them are not covered by public pensions and therefore save more for old age. Also, civil servants save more in absolute terms than the average household; this is due mainly to the higher average income of civil servants (who benefit from a very generous old-age pension system). In Figure 3, we present a cohort analysis of total savings, again in levels. This analysis is better suited to assess the pure age profile of savings because age and cohort effects can be distinguished. Note that the savings profile is roughly hump-shaped as predicted by standard life-cycle models. However, only two age-cohort observations show negative saving after retirement, while the majority of households seems not to dissave after retirement. This is in stark contrast to the predictions of the pure life-cycle model.

The same conclusion holds when we look at saving rates. Figure 4 shows saving rates for our three occupation groups. The difference between all households and civil servants is now smaller, as using saving rates allows to control for differences in the levels of net income over the life cycle. Again, we control for cohort effects in a second picture (Figure 5), and the conclusion is the same as before: The age profile of saving rates exhibits the hump shape predicted by life-cycle models until retirement. After the age of 60, however, saving rates do not decline as predicted by the standard model, but rise again. Although measurement problems might be a problem for the oldest old, a violation of the standard life-cycle model's predictions cannot be disputed.

To summarize these empirical results: First, we have documented just another instance in which the standard life-cycle model is rejected by the data – in this case using very detailed household data from Germany.[4] Second, there are considerable differences in the levels of the age-profiles of both net income and savings between occupation groups that vary in income risk, a fact that needs to be accounted for when simulating and evaluating savings profiles based on some variant of the life-cycle model.

[4] Similar findings have been obtained earlier, using the 1978 and 1983 waves of the EVS, by Börsch-Supan and Stahl (1991) and Börsch-Supan (1992).

3 A model of savings decisions under life-time and earnings uncertainty

We now present a life-cycle model of savings decisions with both life-time and income uncertainty. We also model liquidity constraints (in an implicit fashion). Section 3.1 describes the basic set-up of the model. Its solution is characterized by an Euler equation in Section 3.2, and in Section 3.3, we show how the resulting policy function can be derived numerically.

3.1 Set-up of the model

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

$$S_t = \begin{cases} 0 & \text{if the individual survives period } t \\ 1 & \text{if the individual does not survive period } t \end{cases}$$

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

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

$$\begin{aligned} A_t &= (1+r)(A_{t-1} + Y_{t-1} - C_{t-1}) && (2) \\ A_\tau &\geq 0 && (3) \\ A_T &\geq 0 && (4) \\ C_t &\leq A_t + Y_t && (5) \end{aligned}$$

Maximization of expected discounted utility given by (3.1) is subject to a number of standard restrictions, an asset recursion (2) and non-negativity conditions for initial and terminal assets (3) and (4). Note that while we require assets to be zero in the terminal period T, the individual might die before T with non-zero assets, i. e., there are accidential bequests in our model. These can even be negative as long as condition (5) holds. We include (5) as an explicit borrowing constraint which states that current consumption cannot exceed the sum of current assets and current labor income. However, we do not to impose this condition explicitly in solving the optimization problem. Instead, we impose the borrowing constraint implicitly.[5] As Schechtman (1976) and Zeldes (1989b) have shown, a borrowing constraint arises endogenously if consumption cannot go to zero in each period (i. e., if the marginal utility of consumption goes to infinity as consumption goes to zero), and if there is a positive probability of income dropping to zero in each period. The former is ensured by an appropriate functional form of the utility function $u(C_t)$, the latter by the specification of the income process.

The income process, Y_t, is formulated in terms of a long-term income component, P_t, as in many standard life-cycle models with income uncertainty (see, e. g., Carroll (1997)).[6] Specifically, we define current income, Y_t, as

$$Y_t = S_t V_t P_t. \tag{6}$$

Here, the long-term income component, P_t, is weighted with two random variables. First, as an extension to the Carroll model, we take into account life-time uncertainty via the "survival" variable S_t. Recall that this variable reflects life-time uncertainty and takes the value 1 as long as the individual is alive while it is set to zero thereafter.

Second, labor income is weighted with V_t, a random variable with unit expectation that allows for periods with zero income. This zero-income variable is specified as

$$V_t = \begin{cases} 0 & \text{w.p.} \quad p \\ 1/(1-p) & \text{w.p.} \quad (1-p) \end{cases} \tag{7}$$

where p is an exogenous probability. The zero-income variable is introduced to assure that borrowing constraints arise endogenously. One can think of these zero-income periods as periods during which the household head is unemployed. After retirement, zero-income periods might be thought of as periods in which unforeseen circumstances (such as large health expenditures) depress disposable income. To keep the model simple, the process that governs these zero income realizations is assumed to be serially uncorrelated.[7]

[5] Deaton (1991) considers *explicit* liquidity constraints.

[6] Note that this long-term income component is not exactly the same as permanent income in the traditional sense, although the literature usually refers to P_t as permanent income.

[7] If a period of zero income is associated with unemployment, one might prefer transition probabilities to be state-dependent. One could generalize the zero-income process used here by specifying an employment state variable that follows, say, a first-order Markov chain, although to our knowledge this has not yet been done in the literature on life-cycle savings decisions.

The long-term income component itself is assumed to follow a random walk with drift, an assumption which is standard in the literature.[8] Earnings shocks affect the income process via the equation

$$P_t = G_t P_{t-1} N_t, \tag{8}$$

where G_t is the exogenously fixed and deterministic rate of wage growth, and N_t is a log-normally distributed random variable with unit expectation and variance σ which captures income uncertainty. Note that when income follows a random walk, a shock to current long-term income shifts the entire path of future income.

Finally, we assume that the utility function is of the constant relative risk aversion (CRRA) type,

$$u(C_t) = \frac{C_t^{1-\gamma}}{1-\gamma}, \tag{9}$$

where $\gamma \geq 1$ is the coefficient of relative risk aversion (and the inverse of the intertemporal elasticity of substitution).

Before we discuss the solution of the model in detail, we want to provide some intuition about the model's properties. Note first, that the intertemporal budget constraint with life-time uncertainty can be written as:

$$\begin{aligned} \sum_{t=\tau}^{T} C_t(1+r)^{\tau-t} &= A_\tau + E_\tau\left[\sum_{t=\tau}^{T} Y_t(1+r)^{\tau-t}\right] \\ &= A_\tau + \sum_{t=\tau}^{T} s_t^\tau (1+r)^{\tau-t} E_\tau\left(Y_t\right) \end{aligned} \tag{10}$$

Second, the solution to the model given by (3.1) – (6) can be characterized by the following first-order condition:

$$u'(C_t) = \frac{1+r}{1+\rho} S_{t+1} E_t\left(u'(C_{t+1})\right). \tag{11}$$

This is a modified version of the standard Euler equation in which next period's expected marginal utility is weighted with the conditional probability of surviving period t.

3.2 Backward solution and the Euler equation

To solve the dynamic optimization model for the case with implicit borrowing constraints, we apply the cash-on-hand approach by Deaton (1991) in the version developed by Carroll

[8] Random-walk income processes have been analyzed by Carroll (1992, 1997), *inter alia*. There are also models in which income does not follow a random walk. For example, some papers consider autoregressive processes with high degrees of persistence (e. g., Skinner (1988) and Bertaut and Haliassos (1997)). As an extreme case, we have also experimented with income processes in which shocks are purely transitory, and we found that when we scale the variance of an i.i.d. income process appropriately, we can generate life-cycle saving rates which are virtually identical to those obtained in this paper where we use a random walk specification.

(1992). Cash on hand, denoted by X_t, is the household's current gross wealth (total current resources), given by the sum of current income and current assets,

$$X_t = (1+r)(X_{t-1} - C_{t-1}) + Y_t. \tag{12}$$

As Deaton (1991) has shown, the solution to the intertemporal optimization problem is a function of cash on hand, so we are looking for a policy function of the form $C_t = C_t(X_t)$. Trivially, the household consumes all remaining wealth in the last period of life, hence

$$C_T = X_T. \tag{13}$$

For the remaining periods, the model can be solved by backward induction starting from the last period, T. Combining (11) and (13), one obtains

$$u'(C_{T-1}) = \frac{1+r}{1+\rho} S_T E\left(u'(X_T)\right). \tag{14}$$

Before deriving the solution for the remeining periods, we normalize consumption and cash on hand by long-term average income, P_t,

$$c_t = \frac{C_t}{P_t} \tag{15}$$

$$x_t = \frac{X_t}{P_t}. \tag{16}$$

Dividing by long-term income, P_t, yields stationarity of c_t and x_t (although the random-walk component of income, P_t, is non-stationary). Using these definitions, we can express cash on hand as a function of last period's consumption and cash on hand, and of current realizations of the stochastic shocks.

$$\begin{aligned} x_t &= \frac{(1+r)(X_{t-1} - C_{t-1})}{P_t} + \frac{Y_t}{P_t} & (17) \\ &= \frac{(1+r)(x_{t-1} - c_{t-1})P_{t-1}}{P_t} + V_t S_t & (18) \\ &= \frac{(1+r)(x_{t-1} - c_{t-1})}{G_t N_t} + V_t S_t & (19) \end{aligned}$$

Substituting this expression in the Euler equation (14), we obtain for period $T-1$:

$$\begin{aligned} u'(c_{T-1}P_{T-1}) &= \frac{1+r}{1+\rho} S_T E\left(u'(x_T P_T)\right) & (20) \\ u'(c_{T-1}) &= \frac{1+r}{1+\rho} S_T E\left(u'(x_T G_T N_T)\right) & (21) \\ &= \frac{1+r}{1+\rho} S_T E\left(u'\left[\left(\frac{(1+r)(x_{T-1} - c_{T-1})}{G_T N_T} + V_T S_T\right) G_T N_T\right]\right) & (22) \end{aligned}$$

The first order condition contains only current consumption; it can therefore be solved numerically, yielding a policy function $c_{T-1} = c_{T-1}(x_{T-1})$. By similar arguments, one can obtain first order conditions that depend only on current consumption for all earlier periods. In general, these policy functions take the form

$$c_t = c_t\left(\frac{(1+r)(x_{t-1}-c_{t-1})}{G_t N_t}) + V_t S_t\right), \qquad \forall \quad \tau \leq t \leq T-1. \tag{23}$$

Expressions (13) and (23) allow to solve the entire intertemporal optimization problem by backward induction and to derive a sequence of optimal consumption decisions, $\{c_t\}_{t=\tau}^{T}$.

3.3 Numerical solution procedure

Numerical solutions are obtained by backward induction, iterating on the Euler equation. We start with the last period, in which $C_T = X_T$ trivially and then iterate on the policy functions (23). The range of possible values for consumption, c, and cash on hand, x, is approximated by a finite grid with 100 values. The upper end-point of the grid is set to 20 times the maximum of the long-term income component, the lower end-point is set to 1 (a consumption level close to zero will never be reached because of the shape of the CRRA utility function we use). The values of the grid are quadratically spaced so that the approximation is finer for lower values of c and x.[9]

By evaluating optimal decisions for all values on this grid, the policy functions (23) can be traced out. This is done repeatedly for each period from $T-1$ through τ. To save on memory, we replace the 100 points of these value functions by fitting a low-dimensional polynomial at each point in time (i. e., we only need to store the coefficients of these polynomials and not all 100 pairs of grid points). In practice, we used third-order polynomials, and experimenting with polynomials of higher order did not improve the results. In our experience, this solution method proved to be very fast and reliable.

4 Comparing empirical and simulated savings profiles

In order to generate life-cycle saving rates from equation (23), we need to specify the values of the model's exogenous parameters. The parameter values used to calibrate the model for our numerical simulations are described in Section 4.1. Simulation results are presented in Section 4.2.

4.1 Calibration

Table 1 contains the parameters common to all household types; these are the preference parameters, the interest rate and the number of planning periods. The values we choose are standard in simulation studies of intertemporal saving decisions (see, e. g., Hochguertel

[9] As we analyze a well-behaved intertemporal optimization problem, the true solution will be approximated to an arbitrary degree as the number of grid points approaches infinity.

(1998)). Survival probabilities are taken from the 1993 life tables for West Germany (see Sommer (1994)). Although we simulate household decisions, we use survival probabilities for males for practical purposes. Survival probabilities for ages 100 and beyond which are not covered by published life tables were set to zero at age 115 (so $T = 115$) and then exponentially extrapolated for ages 100 through 115. Note that the conditional probability of surviving another year for a 100 year male is still 37%, so these probabilities are not negligible. The planning age is $\tau = 20$.[10]

Table 1: Parameter values used for calibration: common to all household types

parameter		all household types
relative risk aversion coefficient	γ	3
rate of time preference	ρ	6%
interest rate	r	3%
conditional survival probabilities	S_t	life-table values
number of simulation periods[a]	$T - \tau$	$115 - 20 = 95$

[a] In the case of no life-time uncertainty, we fix $T = 80$.

Table 2 lists the parameters of the income processes for all households and for two subgroups, civil servants and self-employed. As mentioned before, we stratify our sample by occupation of the household head to allow different degrees of income risk. Civil servants are taken as a typical low-risk group, while self-employed are taken as a high-risk group. Standard deviations and zero income probabilities are chosen to reflect these differences. For example, the standard deviation of the income process faced by a self-employed household head is taken to be twice as large as that of other household types. Moreover, the zero income probability of civil servants is assumed to be much smaller (0.2 %) and that of the self-employed much higher (2.0%) than the 1% probability we assign to the group of all households.[11] The table also contains the value of the starting income at planning age ($\tau = 20$); it is given by the mean of net labor income for each group computed from the EVS. The deterministic income growth rates, G_t, are not reported in detail. They are computed to match the shape of the empirical income profiles for each occupation group which are shown in Figure 1.

[10] When we simulate the model with no life-time uncertainty (Figure 7 below), we fix the planning horizon at age 80, the conditional life expectancy at the planning age 20.

[11] We cannot provide better estimates of the empirical income profiles given the limitations of our dataset. Thus, the values we assign should be taken to reflect the relative differences of these occupation groups rather than exact point estimates. Fitzenberger *et al.* (1997) provide the most detailed analysis of wage dynamics in (West) Germany available to date; their analysis is based on detailed longitudinal wage data for the 1976–84 period that were collected by the German labor authorities. The income processes we use are qualitatively consistent with their findings.

Table 2: Parameter values used for calibration: income processes by household type

parameter		all households	civil servants	self-employed
starting net labor income[a]	Y_τ	DM 22,350	DM 29,000	DM 38,750
standard deviation	σ	0.2%	0.2%	0.4%
zero income probability	p	1.0%	0.2%	2.0%

[a] *Source*: EVS 1978–93; own calculations. In 1991 prices.

4.2 Simulation results

We begin by looking at the consequences of including life-time uncertainty in the standard life-cycle model with no income uncertainty. Figure 6 depicts the resulting age-savings profile. The profile exhibits the well-known hump shape: Negative savings in the early years of the working life, increasing saving rates until the age of about 50 years when income reaches its peak (see Figure 1), then declining savings with negative savings during retirement. Finally, saving rates increase again for those happy few who happen to be still alive at 90. This is due to the fact that seen from the planning age of 20, life expectancy is about 80 so that most resources will be spent by this age. By construction, the saving rate is zero at the age of 115, the planning horizon and the age at which all people die in our model (even though there is life-time uncertainty over the entire life cycle). For the remaining simulations, we show age-savings profiles only until the age of 80.

From Figures 7 and 8, one can see how introducing life-time uncertainty affects saving in the standard model with income uncertainty. Without life-time uncertainty (and a planning horizon fixed at age 80), predicted savings during working life are much too high (Figure 7). Introducing life-time uncertainty (with a planning horizon of age 115 and life-table survival probabilities) improves the life-cycle profile of saving rates considerably as can be seen from Figure 8.

Next, we consider the effects of allowing for different income processes in the model with both life-time and income uncertainty. Figure 9 depicts simulated and empirical saving rates for low-risk civil servants, and Figure 10 for the high-risk self employed. Our simulations show that the self employed (high income risk, higher levels of income) should save more than the average household, while civil servants who face only modest degrees of income variability (regarding both income level and variance) should save less. Comparing simulated and empirical saving rates, one can see that our life-cycle model correctly predicts differential peak saving rates during working life for the three household types.

However, the life-cycle model with life-time and income uncertainty cannot explain an important salient feature of saving in Germany. Empirically, there is almost no post-retirement dissaving – and hence no distinct hump shape in saving, both in levels and in saving rates. Our life-cycle model, however, predicts substantial dissaving (as do all standard variants of the life-cycle model). This prediction comes about for all household types we consider, even though by using empirical income processes, we control for the generous German pension system which results in relatively high post-retirement income. Recall that these simulations are based on calibrated income processes that differ in starting income, in the deterministic income growth rates (and hence income levels) over the life cycle, and in income variance.

5 Conclusions

In this paper, we have analyzed a model of life-cycle savings decisions which incorporates both life-time and income uncertainty (together with implicit liquidity constraints). We simulated life-cycle savings profiles based on empirical labor earnings processes estimated from West German household data and compared these simulated profiles with their empirical counterparts.

Our approach extends the existing literature on life-cycle savings decisions in two respects. First, in our theoretical model and in the simulation analysis, we allow for both life-time and income uncertainty. Second, we consider households which differ in both the shape of their income profiles over the life cycle and in income risk. In the simulation analysis of our model, we use time-varying income growth rates estimated from panel data and calibrate variances to allow for differential income risk. Taken together, these modifications of the standard life-cycle model allow us to gain further insights into the nature of precautionary and buffer-stock saving and to re-assess the life-cycle model's ability to explain observed savings behavior.[12] Our main findings are, first, that the life-cycle shapes of simulated saving rates for the three income types differ considerably, and second, that allowing for mortality risk improves the life-cycle model's predictions slightly.

Regarding the empirical results, there are good news and bad news. For the good news, our simulated saving rates qualitatively match their empirical counterparts in the sense that they predict different peak saving rates during working life – specifically, these are much higher for the self employed in both our simulations and in the data. This is due to the fact that the self employed face higher income risk and typically do not have access to the public pension system. For the bad news, none of the models we consider captures an important salient feature of savings profiles derived from German household data: Empirically, we find almost no post-retirement dissaving. This is in stark contrast to all variants of the life-cycle model which predict saving to become negative after retirement.

[12] Börsch-Supan *et al.* (1999b) take a broader view on how the standard life-cycle model can be modified in order to reconcile its theoretical predictions with the existing empirical evidence. In particular, they discuss the issue of whether savings profiles generated by different life-cycle models are empirically identified.

Note that this theoretical prediction arises even in our simulations where we use *empirical* post-retirement incomes (including pensions). Compared with many other countries these are higher in Germany due to its generous pension system. In our simulations, this results in predicted dissaving which is slightly less than in models calibrated to, say, the U.S. pension system (see, e. g., Hochguertel (1998)).

There are a number of extensions which one might consider in this line of inquiry. For example, it would be interesting not only to use the means of income and saving for each occupation group in our analysis, but to use different percentiles of the income distribution in order to check how life-cycle models predict savings away from population means, in the upper and lower end of the income distribution. Also, we simulate saving rates, i. e., we focus on total saving. As noted for example by Guiso *et al.* (1996) and Hochguertel (1998), differences in income risk might affect not only the level of saving, but also portfolio choice. Hence, one might wish to investigate the composition of households' assets in the empirical analysis. Finally, we have already noted in the introduction that treating labor supply and retirement decisions as exogenous is a serious shortcoming in much of the literature on life-cycle savings decisions. These are issues left to future research.

To gain a better understanding of savings decisions is not only a challenging theoretical exercise – it is also central to applied policy analysis. For example, the current debate on reforming social security requires reliable models of household behavior to simulate the consequences of population aging and suggested policy reforms. Although the version of the life-cycle model we considered in this paper does not quite succeed in predicting observed savings behavior, we have shown that the modifications we introduced improve its performance. We therefore believe that allowing for mortality risk and differential income uncertainty is a step in the right direction. There are still many interesting issues that can be persued following this line of research; this is particularly true for many peculiar features of saving behavior in Germany which are induced by its public pension system and other institutional arrangements.

Data Appendix

The microdata we use in this paper are taken from the 1978, 1983, 1988 and 1993 waves of the *Einkommens- und Verbrauchsstichprobe* (EVS), a dataset that is roughly comparable to the U.S. Consumer Expenditure Survey (CEX). The EVS is based on a quinquennial survey conducted by the Federal Statistical Office. However, the EVS is not a panel study but rather consists of repeated cross-sections. The EVS is designed to cover about 0.3 percent of the household population, but unfortunately, it is top-coded – it excludes (approximately) the top 2 percent of the income distribution. In 1993, East Germany was covered for the first time.

For the purpose of this simulation study, we need two income measures and a measure of total household expenditures. The income measure used in the earnings profiles that enter our simulations is *net income* defined as the sum of net labor income and the net balance of recurring public and private transfers. Note that this income measure excludes interest on current assets and non-recurring private transfers because these income components would distort our simulations of life-cycle savings decisions. Savings are constructed as the difference of *disposable income* (net income as described before, plus non-recurring transfers such as bequests and *inter vivos* transfers) and *total expenditures*. We use only data on West German households and exclude households headed by foreigners. Unless noted otherwise, observations from all four EVS waves are pooled (in real terms).

The definitions of the two income measures are summarized in Table 3; the definition of total expenditures is contained in Table 4. A detailed discussion of measurement problems encountered in constructing theses measures from the four EVS waves is available in Börsch-Supan *et al.* (1999a); that paper concentrates on the efforts made to ensure consistency of variables across all four waves – a task which proved quite challening task because of the many changes in the survey design, especially between the earlier waves and the 1993 EVS.

A number of issues are worth mentioning. In Germany, contributions to the public pay-as-you-go pension system are mandatory for a large fraction of the population (excluding most of the self-employed, however). We treat these contributions like taxes; hence, they reduce disposable income and are not part of household saving. Symmetrically, pensions are generally treated as part of the household's income, so they do not imply dissaving during retirement. However, contributions to funded pension plans are treated as saving, and pension received from such schemes are treated as dissaving. An important fraction of private saving in Germany consists of whole life insurance (i. e., life insurance policies that include a saving plan). It is difficult to separate the savings portion of life insurance policies with EVS data, and we need to use some approximations here (see Walliser and Winter (1998) for a discussion). Another serious shortcoming of the EVS is poor data on consumer durables. Because we do not have the reliable historical cost data we would need to construct stocks and users costs for durables (even for motor vehicles), we treat

Table 3: Definition of net income

	income components
gross income	gross labor income
	recurring public transfers, including pensions
	net balance of recurring private transfers
	non-recurring private transfers (if less than DM 2,000)
./. taxes etc.	income taxes, including church rates
	property taxes
	mandatory contributions to social security,
	including contributions to the public pension system
	voluntary contributions to the public pension system

Note: Disposable income is defined as net income plus interest and dividend income on current assets, plus the net balance of non-recurring private transfers in excess of DM 2,000 (e. g., bequests and *inter vivos* transfers).

Table 4: Definition of total expenditures

	expenditure components
private consumption	food, clothing, etc.
	rents
	electricity, gas, etc.
	consumer durables
	health care
	transport and communication
	education, entertainment, leisure
	other private consumption
misc. taxes	taxes on bequests and *inter vivos* transfers
	motor vehicle tax
	other taxes
insurance fees	voluntary contributions to public and private health insurance
	motor vehicle insurance
	legal, liability, accident insurances
	other private insurances

expenditures for durables entirely as consumption. Finally, while we treat housing wealth as part of the household's total wealth and related flows as saving and dissaving, there are a number of difficult issues related to current expenditures for owner-occupied vs. rented housing. For details, we refer to Börsch-Supan *et al.* (1999a) and Schnabel (1998).

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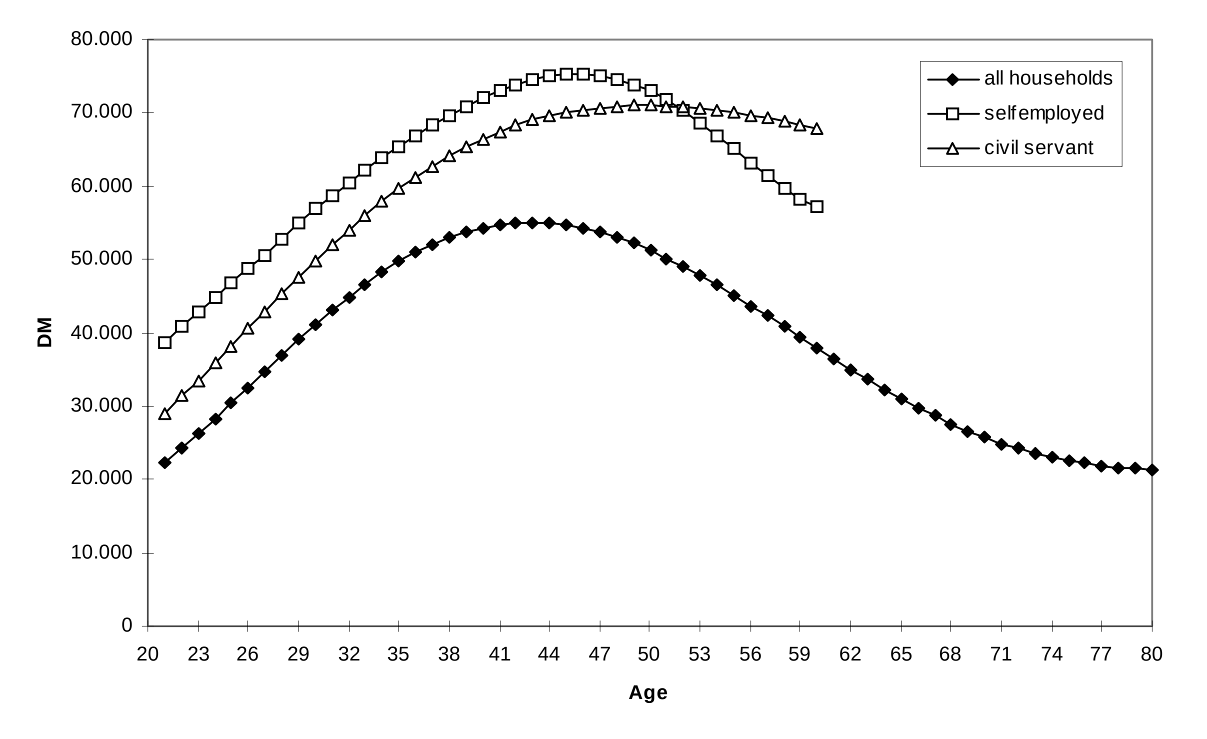
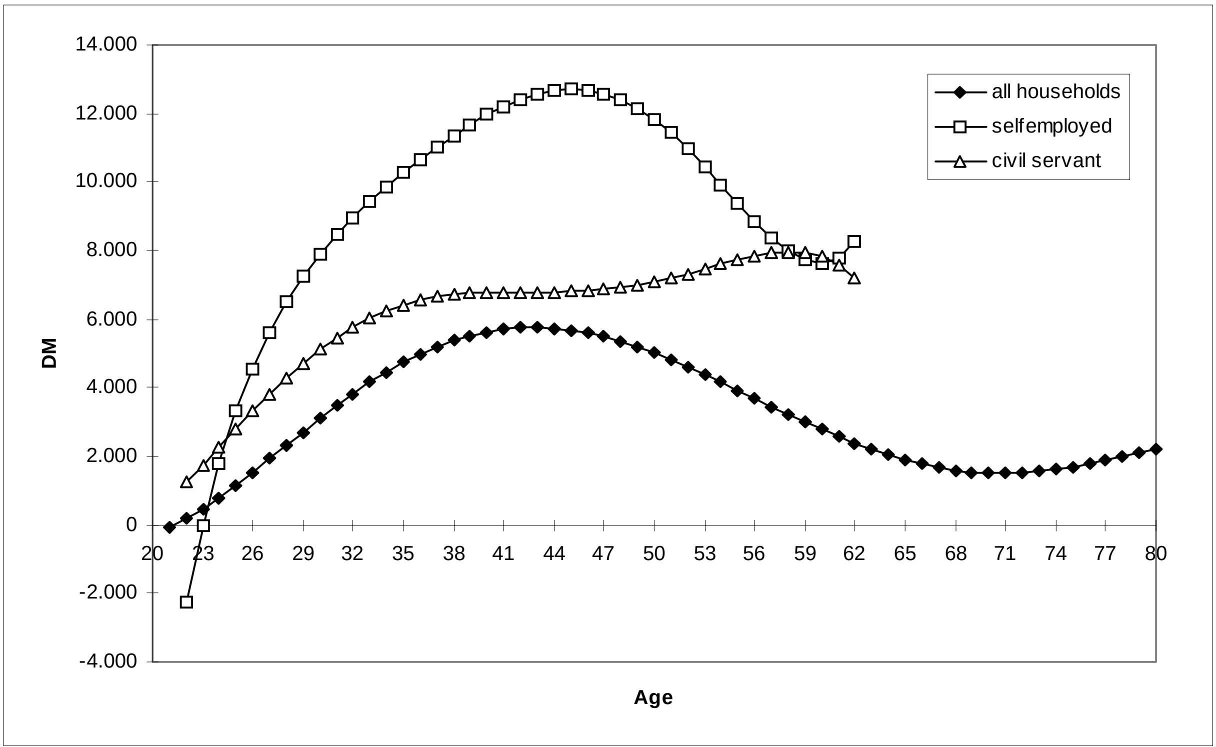
Figure 1: Empirical net income profiles



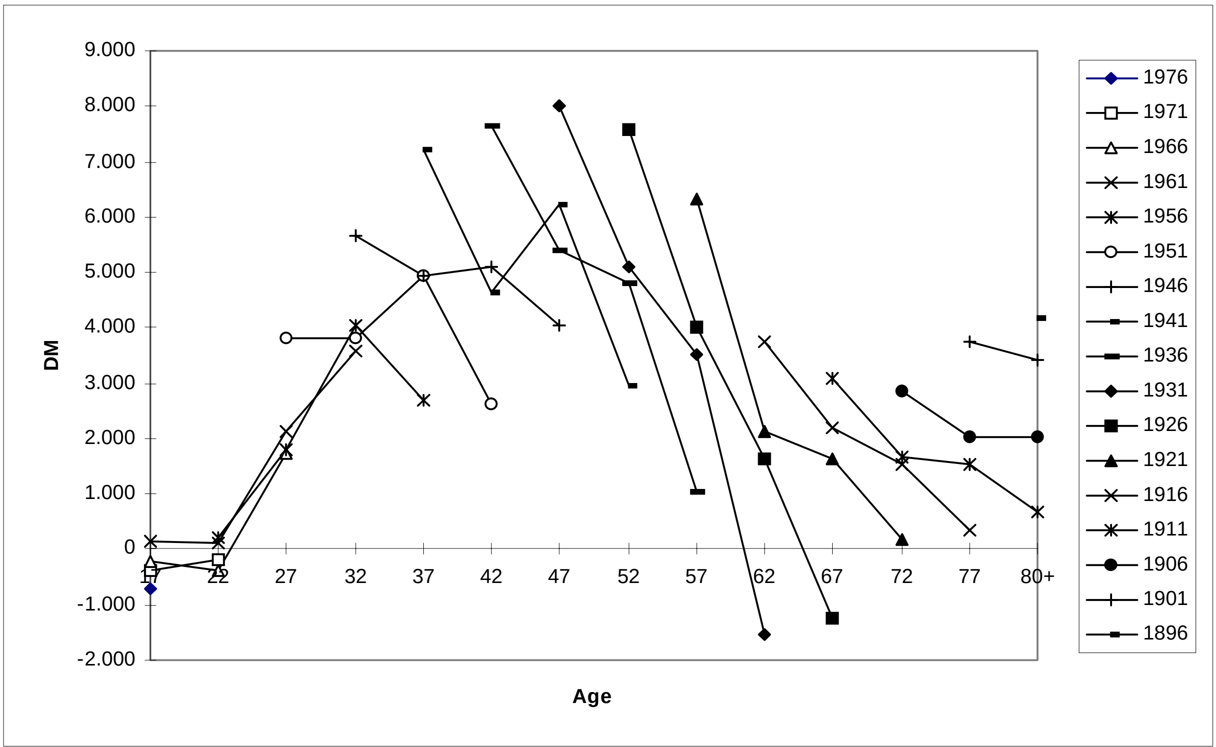
Source: EVS 1978–1993; own calculations. In 1991 prices.

Figure 2: Empirical savings profiles



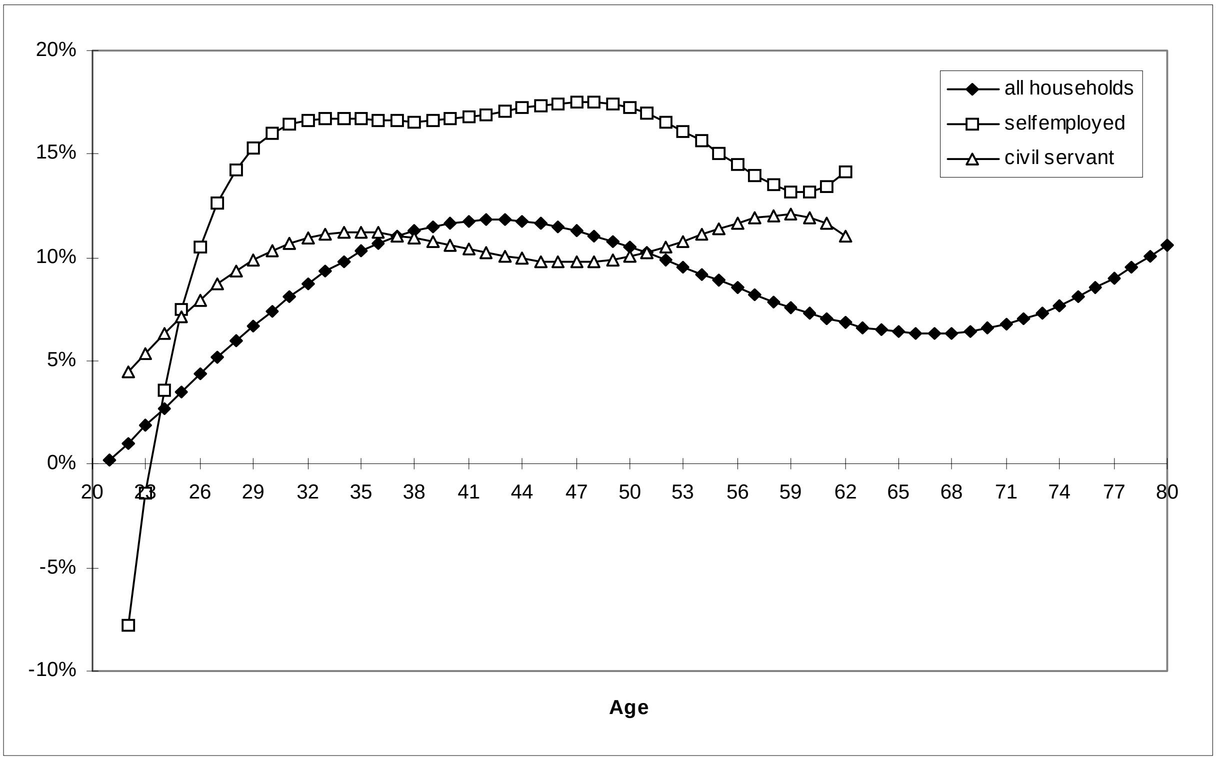
Source: EVS 1978–1993; own calculations. In 1991 prices.

Figure 3: Empirical savings profiles: cohort analysis



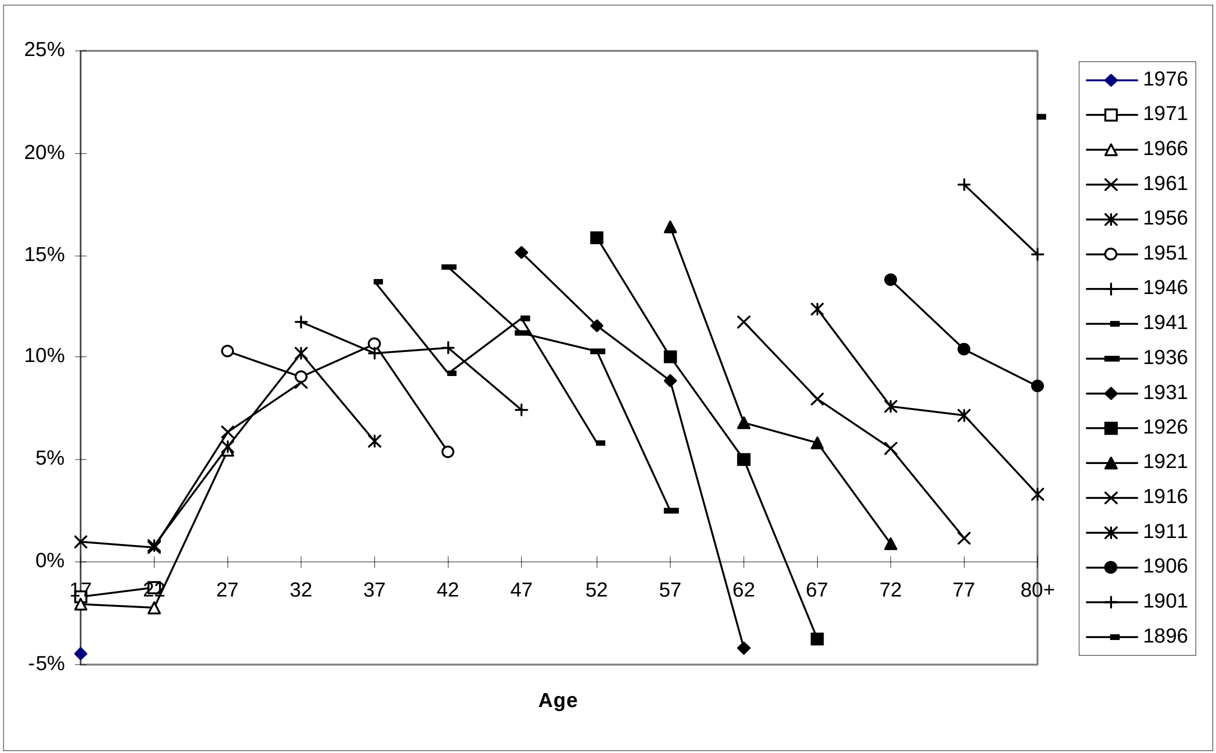
Source: EVS 1978–1993; own calculations. In 1991 prices.

Figure 4: Empirical saving rates



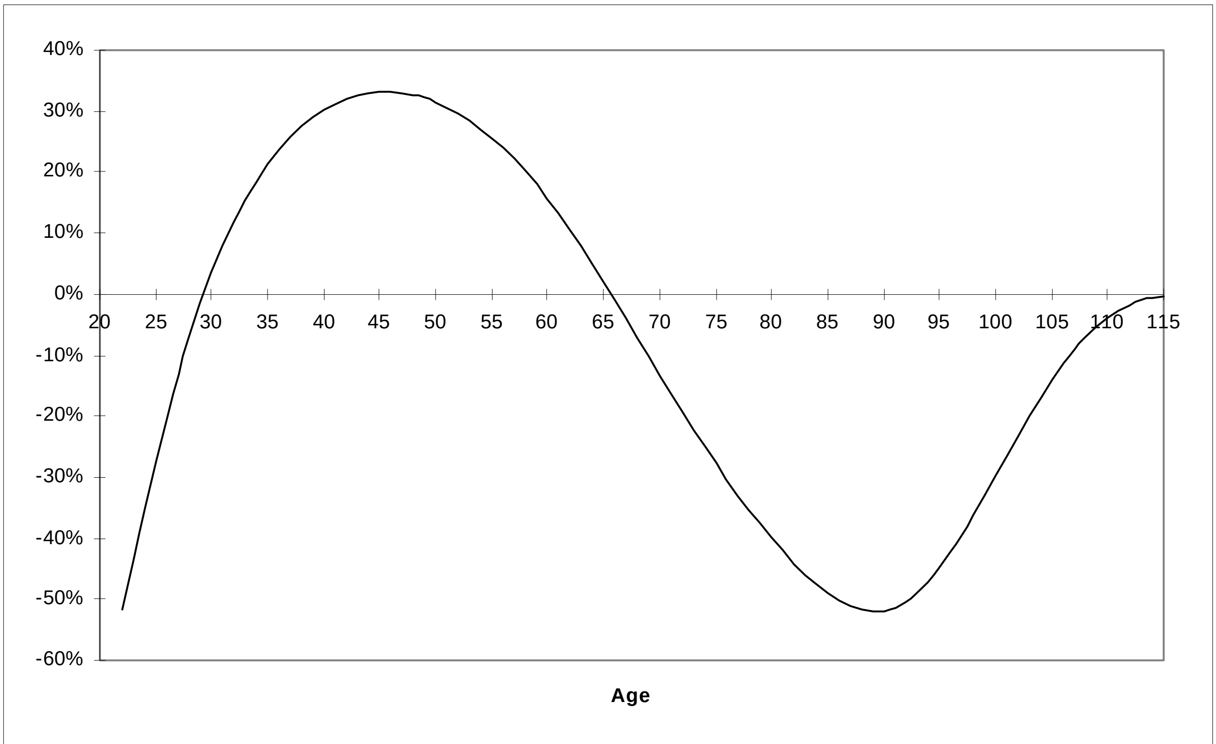
Source: EVS 1978–1993; own calculations.

Figure 5: Empirical saving rates: Cohort analysis



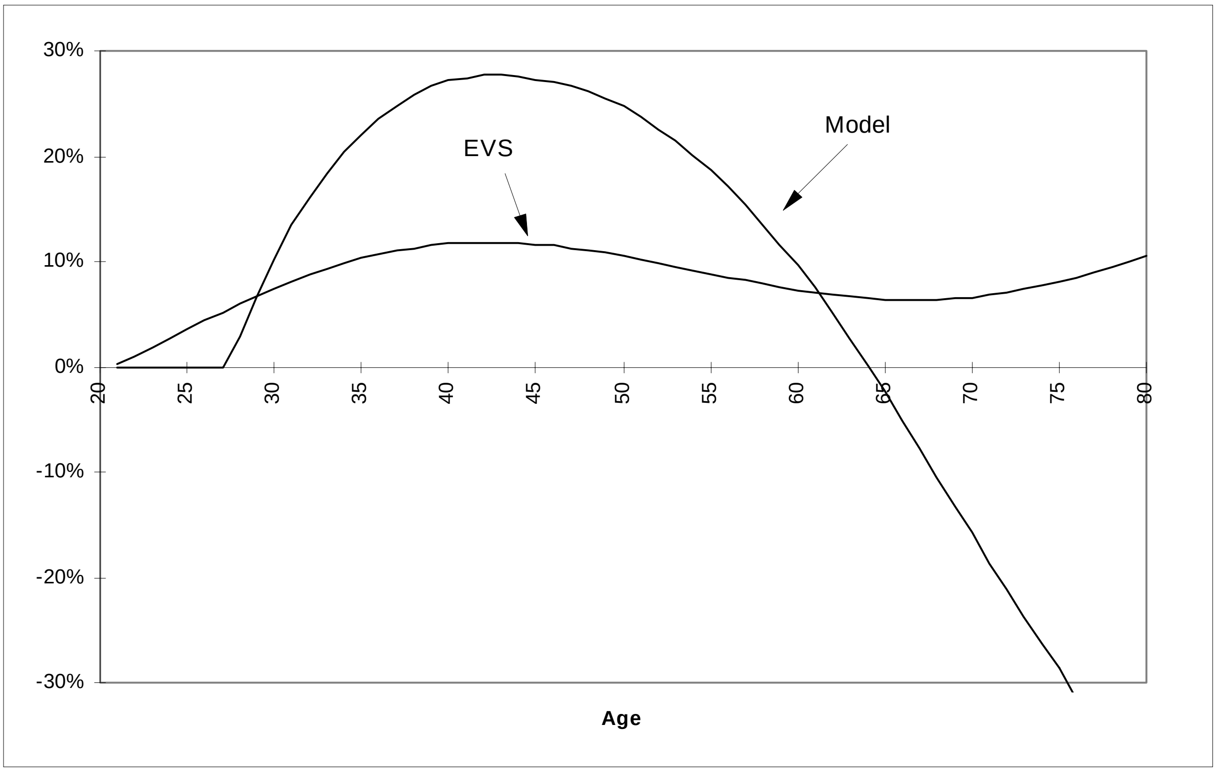
Source: EVS 1978–1993; own calculations.

Figure 6: Simulated saving rates: no income uncertainty, life-time uncertainty, all household types



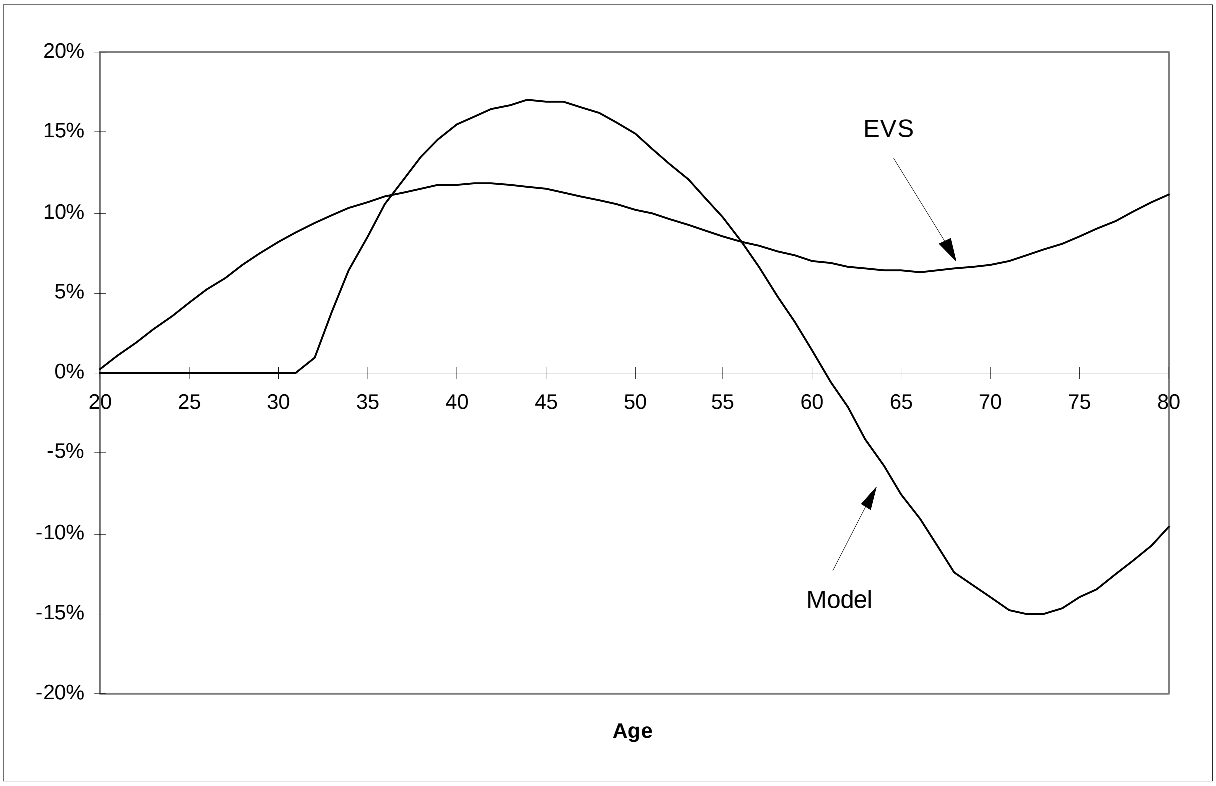
Source: own calculation

Figure 7: Simulated saving rates: random walk income, no life-time uncertainty, all household types



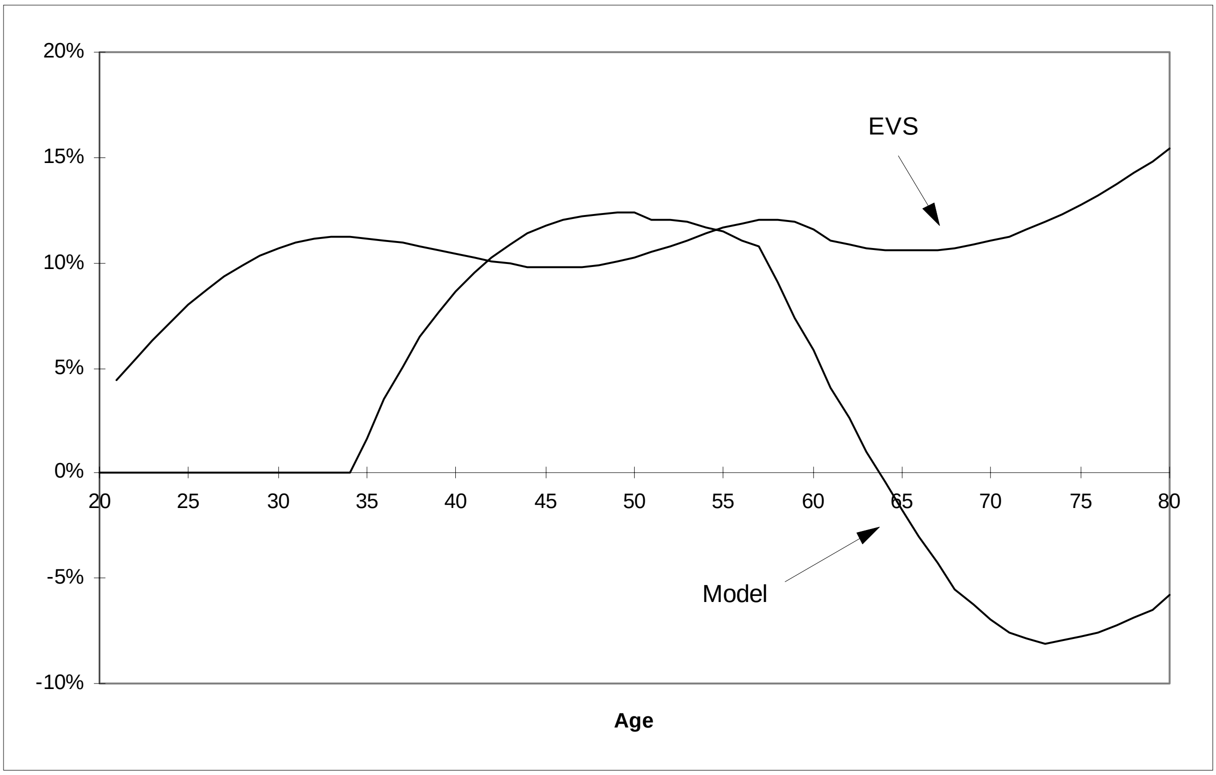
Source: EVS 1978–1993; own calculations.

Figure 8: Simulated saving rates: random walk income, life-time uncertainty, all household types



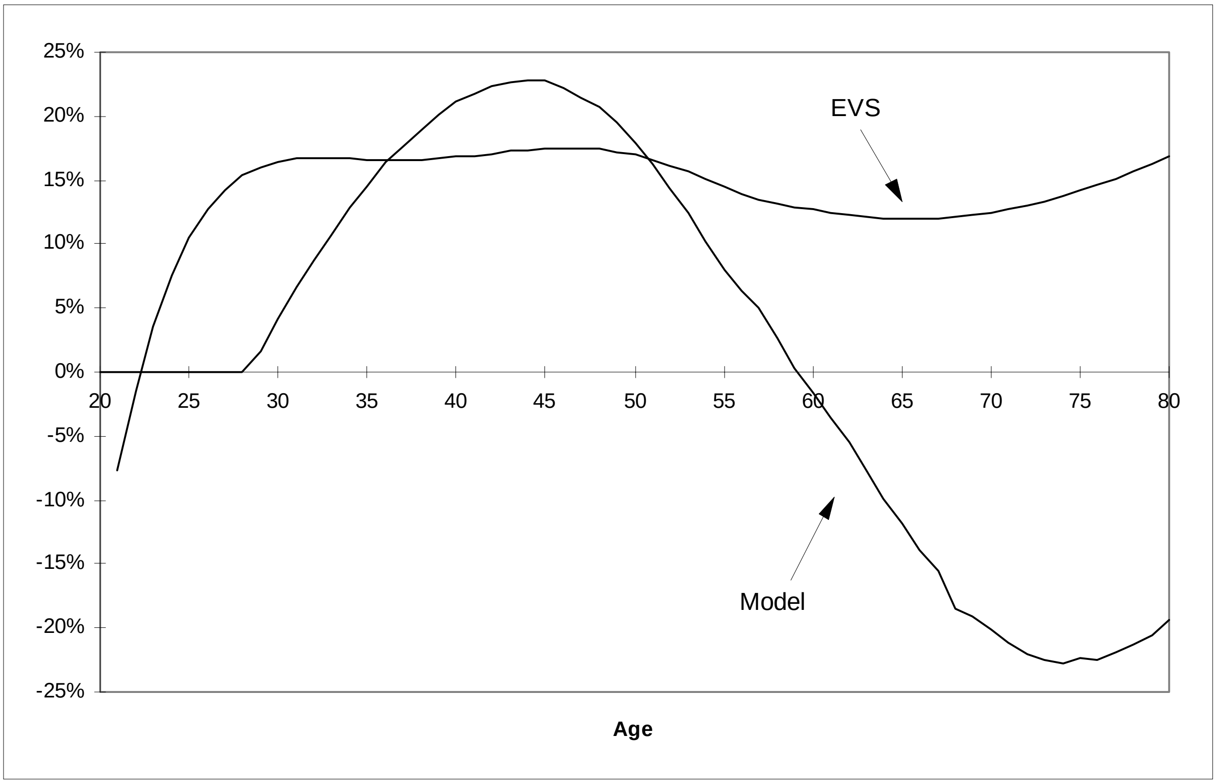
Source: EVS 1978–1993; own calculations.

Figure 9: Simulated saving rates: random walk income, life-time uncertainty, civil servants



Source: EVS 1978–1993; own calculations.

Figure 10: Simulated saving rates: random walk income, life-time uncertainty, self-employed



Source: EVS 1978–1993; own calculations.

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