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Health-Related Life Cycle Risks and Public Insurance

Daniel Kemptner

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Health-Related Life Cycle Risks and Public Insurance*

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Abstract

This paper proposes a dynamic life cycle model of health risks, employment, early retirement, and wealth accumulation in order to analyze the health-related risks of consumption and old age poverty. In particular, the model includes a health process, the interaction between health and employment risks, and an explicit modeling of the German public insurance schemes. I rely on a dynamic programming discrete choice framework and estimate the model using data from the German Socio-Economic Panel. I quantify the health-related life cycle risks by simulating scenarios where health shocks do or do not occur at different points in the life cycle for individuals with differing endowments. Moreover, a policy simulation investigates minimum pension benefits as an insurance against old age poverty. While such a reform raises a concern about an increase in abuse of the early retirement option, the simulations indicate that a means test mitigates the moral hazard problem substantially.

Keywords: dynamic programming, discrete choice, health, employment, early retirement, consumption, tax and transfer system.

JEL Classification: C61, I14, J22, J26

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1 Introduction

The strong association between health and socio-economic status is a very robust finding and is discussed by a large body of literature (see David and Lleras-Muney (2012) or Grossman (2006) for overviews). While there is little robust evidence that income affects health in developed countries¹, there is strong evidence that a substantial share of income inequality can be explained by health (Deaton (2003)). Health status is found to be one of the main determinants of labor market participation and early retirement. Both unemployment and early retirement reduce an individual's expected life cycle income with potentially long-lasting impacts on wealth accumulation. As pointed out by Deaton (2003), this is due to the fact that individuals cannot fully insure their earnings against health risks. Since health shocks affect the dynamics of employment, early retirement, and wealth accumulation, a structural econometric analysis of health and economic outcomes should take into account the relevant processes and individuals' expectations about the consequences of their decisions. There are several recent studies that analyze wage and employment risks within a life cycle framework (e.g. Low (2005), Heathcote, Storesletten, and Violante (2009), Low, Meghir, and Pistaferri (2010), Adda, Dustmann, Meghir, and Robin (2013)). This study adds to the literature on life cycle risks by proposing a dynamic life cycle model of health risks, employment, early retirement, and wealth accumulation in order to analyze the health-related risks of consumption and old age poverty. In particular, the model includes a health process, the interaction between health and employment risks, and an explicit modeling of the German public insurance schemes, where unemployment insurance and early retirement constitute a partial insurance against work incapacity. Moreover, a policy simulation relates to an idea of Golosov and Tsyvinski (2006) and investigates means-tested minimum pension benefits as an insurance against old age poverty.

Following a tradition of structural dynamic retirement models (e.g. Rust and Phelan (1997); French (2005); van der Klaauw and Wolpin (2008); French and Jones (2011); and Haan and Prowse (2011)), I rely on a dynamic programming discrete choice (DPDC) framework. The model is estimated using data from the German Socio-

¹Adda, Banks, and von Gaudecker (2009) find no effect of permanent income shocks on a wide range of health measures.

Economic Panel (SOEP) by applying an extension of the Expectation-Maximization (EM) algorithm to obtain good starting values for a subsequent full information maximum likelihood (FIML) estimation. The analysis focuses on single males and, thus, allows abstracting from adjustments of a partner's labor supply and retirement behavior while the analyzed mechanisms are also relevant for couples and single females. I quantify the health-related life cycle risks by simulating scenarios where health shocks do or do not occur at different points in the life cycle for individuals with differing endowments. A comparison of simulated consumption paths between the scenarios sheds light on the health-related risks of consumption and old age poverty that are uninsured by the German social security system. The results of this analysis motivate the simulation of minimum pension benefits that protect individuals from the risk of old age poverty. While such a reform raises a concern about an increase in abuse of the early retirement option, the simulations indicate that a means test mitigates the moral hazard problem substantially. This finding may also apply to other countries with similar institutions.

DPDC models provide a good framework for the estimation of structural life cycle models. Under the assumption of revealed preferences, micro data can be used to estimate parameters that characterize the preferences and beliefs of forward looking individuals. Starting with the paper of Wolpin (1984), a literature on structural life cycle models has evolved that estimates increasingly complex models (see Aguirregabiria and Mira (2010) for an overview). A big advantage of structural models lies in the possibility to perform *ex-ante* counterfactual simulations. However, estimating these kinds of models requires solving a dynamic programming problem that is nested in the estimation criterion. If the state space is large and if unobserved heterogeneity is allowed for, computation can be burdensome. This paper resorts to an extension of the EM algorithm to obtain good starting values for a subsequent FIML estimation. The extended EM algorithm has been proposed by Arcidiacono and Jones (2003) for the estimation of finite mixture models with time-constant unobserved heterogeneity. The algorithm allows for a sequential estimation of the parameters (see Arcidiacono (2004,2007) for other applications).

To the best of my knowledge, this is the first study that analyzes the health-related risks of consumption and old age poverty by estimating a structural life cycle

model. However, previous studies use structural models to investigate the link between health and the economic situation of households. Bound, Schoenbaum, Stinebrickner, and Waidmann (1999) and Disney, Emmerson, and Wakefield (2006) show that older workers who are in good health status are more likely to be employed, French (2005) finds that health affects labor force participation rates more than hours worked, and Blau and Gilleskie (2008) estimate that bad health halves the employment probability of older employees who have health insurance in the US. Some studies estimate effects on wealth accumulation using a life cycle model. While de Nardi, French, and Jones (2010) show that health costs explain a large share of saving behavior in the US, French and Jones (2011) investigate the effect of life expectancy on optimal saving behavior of retirees and Haan and Prowse (2011) use a life cycle model to estimate the effects of an exogenous increase in life expectancy on employment, retirement behavior and savings in Germany. Low and Pistaferri (2011) analyze the insurance value of disability benefits and incentive costs within a life cycle framework.

Average pension benefits of early retirees who enter early retirement due to bad health have declined nominally from €706 to €600 between 2000 and 2010 in Germany, and each year about 160,000 of these early retirees are registered newly with the German statutory pension insurance scheme (Deutsche Rentenversicherung (2011)). Since pension benefits are the only income source of about one in two of these early retirees (Albrecht, Loos, and Schiffhorst (2007)) and individuals who are in bad health status usually cannot compensate for reductions in the level of pension benefits by delaying retirement, there is a concern of health-related poverty. My simulations suggest that both the risk of old age poverty and health-related changes in this risk depend substantially on an individual's endowments and that the health-related changes may be sizable. The simulated health-related losses in the net present value (NPV) of expected lifetime consumption at age 40 that are uninsured by the German social security system range between 3% and 7%. Expected losses can be severe if a health shock occurs at an early stage of the life cycle. The simulations of the introduction of minimum pension benefits at the poverty line indicate only a small decrease in individuals' expected retirement age if the minimum benefits are means-tested (between 0 and 0.4 years depending on endowments). For a non-means-tested scheme, the simulations suggest a severe moral hazard problem.

The paper is structured as follows. I begin with a description of the data and institutional framework. Then, I proceed with an outline of the life-cycle model and estimation approach before discussing the parameter estimates and model fit. The following section presents the policy analysis on the health-related consumption and poverty risks and the counterfactual reform. A final section sums up the main findings of the analysis.

2 Data and descriptive statistics

My analysis is based on data from the German Socio-Economic Panel (SOEP), which collects annual information at both the household and individual levels (Wagner, Frick, and Schupp (2007)). I construct an unbalanced panel covering the years 2004 through 2010.² The sample is restricted to single males aged 40 to 64 years with no children in the household. Self-employed, civil servants, and people in institutions are also excluded from the sample. I consider the age cohorts 40 to 64 because early retirement is rarely observed in younger cohorts. As a consequence, the simulations are performed for given endowments at age 40. The focus on single males allows abstracting from adjustments of a partner's labor supply and retirement behavior while the analyzed mechanisms are also relevant for couples and single females. The final sample consists of 594 independent and, in total, of 2,016 observations. Early retirees are only contained in the sample in the first year of retirement because retirement is modeled as an absorbing state and estimation of the model does not require data on individuals after retirement. There are 57 individuals who opt for early retirement during the observation period. The consumer price index is used to adjust nominal variables to 2005 prices. Table 1 presents some descriptive statistics on the variables that are used in the analysis. These variables are discussed in more detail in the following paragraphs.

Health status: The SOEP provides annual information on individuals' health status by both a measure of legally attested disability status and of self-assessed health

²The model is estimated for the waves after the 2005 reform of the German income tax system. On January 1, 2005, a reform of the German tax system came into effect lowering the marginal tax rates and making some changes to the tax base. The focus on waves with a relatively homogeneous institutional framework facilitates the computation of the value functions (see below). The survey year 2004 is only included to provide information for the lagged variables of the model.

Table 1: Descriptive statistics

Variable	Mean	Std.	Min	Max
Age	49.5	6.71	40	64
Good health	0.74	0.44	0	1
Employed	0.72	0.45	0	1
Wage (€)	16	5.67	7.52	34.8
Years of education	12.4	2.46	7	18
Work experience	24.6	8.47	1	48
East Germany	0.3	0.46	0	1
Total savings (€)	3,154	4,243.5	0	33,335
Net wealth (€)	78,310	132577.7	-342,971	1,146,697

(SAH). Legally attested disability is based on a medical examination and has the advantage of being comparatively objective. However, there may be a lag between the realization of a health shock and the completion of the process leading to the approval of the disability status. Moreover, this measure may not capture some forms of mental illnesses or physical impairments that are relevant when investigating the effects of bad health on economic outcomes.³ Therefore, I combine the objective disability measure with the subjective SAH measure that presumably captures a broader range of health problems and is found to reflect longitudinal changes in the objective health status reasonably well (Benitez-Silva and Ni (2008)). I construct a binary health measure defining good health as neither being officially disabled nor assessing own health as “bad” or “very bad”. By this definition, about three quarters of the individuals in the sample are in good health status. I observe 150 transitions from good to bad health status and 115 transitions from bad to good health status.

Labor market: Since part-time employment is empirically irrelevant for single males, employment behavior is only differentiated between non-employment and full-time employment. Employment is defined as working at least 20 hours per week and the median hours of work for the employees is 40. The share of employed individuals amounts to 72% in the sample. Observed gross wages range from €7.52 to €34.8 per hour, the median wage being €15.2.⁴ Education is measured as years of education. The SOEP constructs the years of education variable from the respondents’ information on the obtained level of education and adds some time for additional occupational training.

³The eligibility criteria of the early retirement scheme are independent of the legal disability status.

⁴Some outliers with wages below €7.5 or above €35 per hour are excluded from the sample.

Work experience is defined as years of full-time experience.⁵ A binary variable indicates residence in West or East Germany, where Berlin is counted as East Germany. By this definition, about 30% of the individuals reside in East Germany.

Wealth and savings: The SOEP contains wealth information only for the years 2002 and 2007. Hence, net wealth must be imputed for the 2005, 2006, 2008, 2009, and 2010 waves. This can be done by using information on the individuals' saving behavior and carrying forward net wealth under some assumptions from the year 2007 to the other survey years.⁶ Some other studies derive annual wealth from information on asset income and home ownership (e.g. Fuchs-Schuendeln and Schuendeln (2005), Haan and Prowse (2011)). However, this measure suffers from weaknesses that follow from unobserved fluctuations in the returns of individual asset portfolios and from the fact that some assets do not generate any annual returns. Average net wealth is €78,787 in the sample, but the median of net wealth is only €23,806. 25% of the individuals do not have any positive net wealth.

I proceed in a similar way as Fuchs-Schuendeln (2008) defining total savings as the sum of financial and real savings. Since saving information in the SOEP is left-censored (dissavings are unobserved), I assume that individuals aged 40 to 64 do not dissave and only decide how much wealth to accumulate until retirement. The SOEP participants indicate their financial savings annually by answering a question about the “usual” amount of monthly savings.⁷ Real savings are defined as annual amortization payments. Since the SOEP question asks for the sum of amortization and interest payments, the share of interest payments must be derived from information on the amount of debts. The average saving rate for my sample population (11.7%) is close to the average household saving rate that has been derived by the federal reserve bank from the national accounts for the survey years under consideration (11%). 31.4% of the individuals do not save any positive amount.

⁵One year of pre-sample part-time experience is counted as half a year of full-time experience.

⁶For this purpose, I assume that individuals borrow money at a real interest rate of 6% and receive a real interest rate of 2% on both their financial and real savings. Under these assumptions, debts and net wealth are carried forward from the year 2007 to the other survey years and amortization payments can be differentiated from interest payments. One observation with net wealth larger than €3,000,000 as well as a few observations with unrealistically high savings are excluded from the sample.

⁷Question: “Do you usually have an amount of money left over at the end of the month that you can save for larger purchases, emergency expenses or to acquire wealth? If yes, how much?” This measure should be unaffected by seasonal fluctuations.

3 Institutional framework

Individuals make decisions within the framework of the German tax and transfer system and statutory pension insurance scheme. My life cycle model incorporates the main features of this institutional framework when computing individuals' net income. In the following, I outline the main aspects of these institutions insofar as they are relevant for single males. The unemployment insurance and early retirement schemes are of particular relevance for my analysis because these schemes constitute an insurance against the health-related life cycle risks.

3.1 Tax and transfer system

Employed individuals have to pay income tax on both their gross wages and capital income.⁸ Moreover, individuals pay mandatory social security contributions for health, pension, and unemployment insurance.⁹ Unemployed individuals are eligible for either unemployment insurance benefits or means-tested social assistance benefits, where the former is proportional to the last net earnings (60% for single households) and the latter ensures a minimum income that does not depend on the individual's employment history. Social assistance benefits comprise a basic amount plus the costs of rent and energy consumption.¹⁰ While unemployment insurance benefits are paid for an entitlement period only, social assistance benefits are paid indefinitely. The entitlement period of unemployment insurance benefits differs by age and employment history.¹¹

3.2 Statutory pension insurance scheme

The statutory retirement age of the individuals is 65 years.¹² After retirement, individuals receive public pension benefits. The benefits are a deterministic function of

⁸The income tax rate increases with an individual's taxable income and is payable on all gross income in excess of the income tax allowance. I simplify the analysis by assuming that all individuals receive a net capital income that amounts to 2% of their net wealth.

⁹Social security contributions are paid at a constant rate on gross income above a lower limit and below an earnings cap, where half of the contributions are paid by the employer. The contributions of the employees amount to 21.5% of the gross wage.

¹⁰In 2005, the basic monthly amount is €345 in West and €331 in East Germany. Individuals are assumed to receive €300 for rent and €50 for energy consumption.

¹¹I assume that all the individuals are entitled for one year of unemployment insurance benefits after becoming unemployed. Similarly to Adda, Dustmann, Meghir, and Robin (2013), this simplification avoids an increase in the state space.

¹²Between 2012 and 2029, the statutory pension age will be gradually increased from 65 to 67 years for the cohorts born after 1954. The analysis abstracts from this reform.

the accumulated weighted pension points that reflect an individual's employment and wage history.¹³ This leads to complicated dynamic incentives that can be captured by a DPDC framework. An individual accumulates one pension point for each year of employment, which is given a weight of $\frac{wage_{nt}}{\overline{wage}_t}$, where $wage_{nt}$ is individual n's wage in year t and \overline{wage}_t is the average wage in year t.¹⁴ Individuals obtain additional pension points for child care, military service, and during periods of unemployment.¹⁵

The possibility of early retirement constitutes an insurance against work incapacity. Eligibility depends on age, employment history, and health status. Individuals with a sufficiently long employment history (more than 35 years of work) are eligible for early retirement if aged 63 or over. Unemployed individuals are eligible if aged 60 or over.¹⁶ Boersch-Supan (2001) points out that unemployment as a transition to early retirement is likely to be endogenous and to be a strategic variable of both the employer and employee. Individuals who are in sufficiently poor health status (work incapacity) can opt for early retirement even before age 60. In this case, they receive pension benefits as if they had worked until age 60. However, this requires a medical examination that is performed by a physician from the statutory pension insurance scheme. While it is hard to believe that individuals who actually are in good health status can easily pass the examination, it appears to be likely that individuals who are in bad health status, but are not work incapacitated, can pass by exaggerating their health problems. For each year of early retirement before the age of 65, 63 for individuals in bad health status, a penalty of 3.6% is applied on the pension benefits. The penalty is applied up to a maximum of 18% of the pension benefits, where this ceiling is reduced to 10.08% for individuals in bad health status. Hence, bad health status opens up the option of early retirement before age 60 and goes along with lower reductions on an early retiree's pension benefits.

¹³In 2005, the value of one pension point amounted to monthly benefits of €26.13 in West and €22.97 in East Germany. Since 2005, pensioners must pay income tax on 50% of their pension benefits. Until 2040, this share will gradually increase up to 100%.

¹⁴There is a year-specific cap on pension point weights, which has been approximately 2 during the observation period.

¹⁵Individuals who receive unemployment insurance benefits also pay social security contributions and receive 0.8 pension points that are weighted according to the last wage. Pension points for individuals who receive social assistance benefits are negligible. I assume that individuals have received unemployment benefits during up to two years of their periods of non-employment when computing the number of pension points.

¹⁶Between 2006 and 2010, the minimum age for unemployed individuals increased from 60 to 63.

4 Model and specification

In the following subsections, I present a detailed outline of the structural life cycle model. After summing up its main features, I proceed with a description of the various components of the model.

4.1 Main features

Methodology: The methodological framework is similar to Rust and Phelan (1997), but - like other recent studies (e.g. van der Klaauw and Wolpin (2008), French and Jones (2011)) - the model accounts for wealth accumulation and time-constant unobserved heterogeneity. Individuals maximize their expected lifetime utility by making choices about employment, early retirement and saving behavior in each period of time (annual data). The set of possible choices is restricted by eligibility requirements for early retirement and by job offer and separation rates that are estimated differentially by health status. Individuals who do not opt for early retirement retire upon reaching the statutory pension age of 65 years. Individuals have rational expectations and face a dynamic programming problem with a finite horizon. Unlike studies that apply a two-step estimation approach (e.g. French (2005), French and Jones (2011)), the model allows for correlations between unobserved heterogeneity in the leisure preferences and the unobserved components in both the health process and wage equation. This accounts for selection into the labor market.

Health: Health is modeled as a binary autoregressive process that depends on lagged health status, years of education, and age. Since it is unobserved whether a health shock leads to a work incapacity, the model assumes that bad health status affects employment and early retirement through the labor market risks (captured by job offer and separation rates), the eligibility requirements for early retirement, and the financial incentives of the early retirement scheme. Low job offer rates induce persistence of unemployment that is taken into account by forward-looking individuals. For this reason, unemployed individuals who are in bad health status may have a strong incentive to opt for early retirement (low opportunity costs). Medical expenditures are not included in the model because they are covered by health insurance and do not affect the individuals' financial situation.

Budget: Wages are estimated within the model (as a function of years of education, work experience, and region of residence) and pension benefits are a deterministic function of retirement age, work experience, and past wages. This induces complicated dynamic incentives that are captured by the DPDC framework. When deciding about employment and early retirement, individuals take into account both the effect of human capital accumulation on wages (Eckstein and Wolpin (1989)) and the effect on future pension claims. Net income is computed by applying the rules and regulations of the German tax and transfer system and statutory pension insurance scheme, where unemployment insurance and early retirement constitute a partial insurance against work incapacity. After retirement, individuals make no more choices and dissave according to the value of an actuarially fair life annuity that could be bought with the accumulated wealth.

The model includes the following **state variables**: individual’s age, net wealth, work experience, years of education, residence in East or West Germany, health status, and previous period’s choices. The **choice problem** consists of two parts: i) an optimal stopping problem regarding early retirement and ii) employment and saving choices.

4.2 Objective function

I specify a DPDC model of individuals’ employment, early retirement and saving choices. Individuals are finitely lived and die no later than period T , which is set to be 100. Discrete time is indexed by t (individual’s age), and there is a number of N individuals, indexed by n . Each individual n receives a utility flow $U(\mathbf{s}_{nt}, d_{nt})$ in period t where \mathbf{s}_{nt} is a vector of state variables, and d_{nt} indicates the individual’s choice. Note that the saving decision is discretized. An individual chooses between nine alternative choices: working and zero, $[500,1500)$, $[1500,5000)$, $[5000,10000)$, or $[10000,\infty)$ EUR of annual savings; not working and zero, $[500,1500)$, $[1500,\infty)$ EUR of annual savings; early retirement (if eligible) and dissaving according to the value of an actuarially fair life annuity that could be bought with the accumulated wealth. Individuals save a non-negative amount before retirement.¹⁷ Individuals are assigned the median savings

¹⁷This assumption is due to a data restriction of the saving information (left-censored). An exception are unemployed individuals who are not eligible for unemployment insurance benefits and fail the means test required for social assistance benefits. These individuals receive an income at the minimum income level that is deducted from their net wealth, where € 10,000 are exempted from the means test

of the respective saving category and retire no later than the statutory pension age of 65 years. Every period t , an individual n observes the state variables \mathbf{s}_{nt} and makes the choice d_{nt} that maximizes expected lifetime utility:

$$E \left\{ \sum_{j=0}^{T-t} p_{t+j} \beta^j U(\mathbf{s}_{nt+j}, d_{nt+j}) \right\} \quad (1)$$

where β is the time discount factor, which is set to be 0.96 (Gourinchas and Parker (2002) provide a reliable estimate) and p_{t+j} is the conditional survival probability of the individual for period $t+j$ given survival until period t . Information on conditional survival probabilities originates from life tables of the Human Mortality Database.¹⁸

4.3 Utility function

Individuals have preferences about consumption and leisure time that are represented by the following time separable random utility model:

$$U(\mathbf{s}_{nt}, d_{nt}) = \alpha_1 \frac{c(\mathbf{s}_{nt}, d_{nt})^{(1-\rho)} - 1}{(1-\rho)} + \alpha_{2n} (1 - work(d_{nt})) + \epsilon_{nt}(d_{nt}) \quad (2)$$

where $\epsilon_{nt}(d_{nt})$ is assumed to be type 1 extreme value distributed. $c(\mathbf{s}_{nt}, d_{nt})$ is the level of consumption that is associated with state \mathbf{s}_{nt} and choice d_{nt} . $work(d_{nt})$ indicates employment such that $(1 - work(d_{nt}))$ captures the leisure time that is associated with either non-employment or retirement. α_1 is a consumption weight and ρ is the coefficient of relative risk aversion (CRRA). Unobserved heterogeneity in the leisure preferences is reflected by α_{2n} . This utility function assumes additive separability between consumption and leisure time as well as its unobserved random component. I also estimated a specification that allows for non-separability between consumption and leisure time. The estimates of the unchanged parameters and the results of the simulations are insensitive to this choice of specification. The vector $\boldsymbol{\theta}_U = (\alpha_1, \rho, \alpha_{2n})$ contains the parameters of the utility function.

that is required for social assistance benefits. The exemption level of €10,000 is assumed because the actual rules are very complicated and enforcement of these rules is unobserved.

¹⁸University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org or www.humanmortality.de (data downloaded on 5.12.2012). I average the age-specific conditional survival probabilities over the years 2005 through 2010, which are the survey years that are used for the estimation of the model. Using different mortality rates by survey year would require the computation of different value functions for each survey year and, thus, increase the computational burden substantially.

4.4 Value function

Individuals' beliefs about future states are captured by a Markov transition function $q(\mathbf{s}_{nt+1}|\mathbf{s}_{nt}, d_{nt})$ indicating the respective transition probabilities. In particular, $q(\mathbf{s}_{nt+1}|\mathbf{s}_{nt}, d_{nt})$ captures expectations of the transitions of the health status that evolve stochastically over time. Furthermore, it takes into account the expectations of unemployed individuals to receive a job offer and of employed individuals to face a job separation in the following period (see below). For state variables like net wealth or work experience that evolve deterministically for given choices, the probability of the determined state is one while it is zero for all other possible states of the variable. Since there is a discrete set of possible future states, $q(\mathbf{s}_{nt+1}|\mathbf{s}_{nt}, d_{nt})$ is a probability mass function and not a density function. By Bellman's principle of optimality, the value function $V_t(\mathbf{s}_{nt})$ can be represented recursively as

$$V_t(\mathbf{s}_{nt}) = \max_{d_{nt} \in D(\mathbf{s}_{nt})} \left\{ U(\mathbf{s}_{nt}, d_{nt}) + p_{t+1} \beta \int_{\epsilon} \left[\sum_{\mathbf{s}_{nt+1}} V_{t+1}(\mathbf{s}_{nt+1}) q(\mathbf{s}_{nt+1}|\mathbf{s}_{nt}, d_{nt}) \right] g(\epsilon_{nt+1}) \right\} \quad (3)$$

where $D(\mathbf{s}_{nt})$ is the choice set that is available to individual n in period t and $g(\cdot)$ is the probability density function of the unobserved random components of the utility function. Individuals only make choices until retirement and the available choice set depends on the individual's state, \mathbf{s}_{nt} . The choice set is restricted by the eligibility requirements for early retirement and by job offer and separation rates that are estimated within the model.

4.5 Job offer and separation rates

An individual's choice of employment is restricted by job offer and separation rates that are estimated within the model. The job offer rates capture persistence of the unemployment status. Individuals who have been unemployed in the previous period may only choose employment if they receive a job offer in the current period. Analogously, individuals who have been employed in the previous period may only choose employment if they do not face a job separation in the current period. The job offer and separation rates are estimated differentially by health status in order to account for the change in labor market risks that is induced by a health shock. If the choice

of employment is restricted, individuals can only choose between unemployment and early retirement (if eligible). It follows from the persistence of the unemployment status - taken into account by forward looking individuals - that unemployed individuals may have a strong incentive to opt for early retirement (in particular when their health status is bad). Individuals receive a job offer with a probability of either ϕ_{gh}^{offer} or ϕ_{bh}^{offer} and face a job separation with a probability of either ϕ_{gh}^{sep} or ϕ_{bh}^{sep} , depending on their health status. The job offer and separation rates are contained by the vector $\phi = (\phi_{gh}^{offer}, \phi_{bh}^{offer}, \phi_{gh}^{sep}, \phi_{bh}^{sep})$.

4.6 Health process

Good health is modeled as a binary autoregressive process that depends on lagged health status, education, and age. This takes into account the high observed persistence of the health status. Education captures differences in the health risks by socio-economic status.¹⁹ The probability of good health is given by

$$P(\text{health}_{nt} = 1) = \Lambda(\psi_1 \text{health}_{nt-1} + \psi_2 \text{educ}_{nt} + \psi_3 \text{age50}_{nt} + \tau_n) \quad (4)$$

where $\Lambda(\cdot)$ is the logistic distribution function, health_{nt} is a binary variable that indicates good health status, educ_{nt} is years of education, and age50_{nt} indicates an age of 50 years or older. The inclusion of age50_{nt} - instead of a linear age measure - as an explanatory variable is in line with the observed health pattern in the data. Unobserved time-constant heterogeneity is captured by τ_n and is allowed to be correlated with the time-constant unobserved heterogeneity in both the utility function and the wage equation. The health process does not include health investments because heterogeneity in health behavior is captured to some extent by education and medical expenditures are covered by health insurance. Since it is unobserved whether a health shock leads to a work incapacity, the model assumes that bad health status affects employment and early retirement through the labor market risks (captured by job offer and separation rates), the eligibility requirements for early retirement, and the financial incentives of the early retirement scheme. The vector $\theta_h = (\psi_1, \psi_2, \psi_3, \tau_n)$ contains the parameters of the health process.

¹⁹Quasi-experimental evidence suggests that education even exerts a causal effect on health and health behavior (see e.g. Kemptner, Juerges, and Reinhold (2011) for Germany).

4.7 Gross wage

Gross wages are assumed to follow a log-normal distribution. The logarithm of gross wages is modeled as

$$\log(wage_{nt}) = \delta_1 educ_n + \delta_2 ex_{nt} + \delta_3 east_{nt} + \kappa_n + \mu_{nt} \quad (5)$$

where $educ_n$ is years of education, ex_{nt} is years of work experience, $east_{nt}$ is a dummy variable for residence in East Germany, κ_n is time-constant unobserved heterogeneity, and μ_{nt} is i.i.d. $N(0, \sigma_\mu)$.²⁰ It follows from the DPDC framework that individuals take into account the human capital accumulation process when making their employment choice (Eckstein and Wolpin (1989)).²¹ Hence, work experience is an endogenous variable in the model. The wage equation does not include $health_{nt}$ as an explanatory variable because it is empirically not relevant.²² The correlation between the individual-specific leisure preferences in the utility function and the unobserved component, κ_n , in the wage equation accounts for selection into the labor market. The parameters of the wage equation are contained by the vector $\theta_w = (\delta_1, \delta_2, \delta_3, \kappa_n, \sigma_\mu)$.

4.8 Budget constraint

Individuals face a budget constraint when making their saving/consumption choice. The constraint comprises three equations:

$$\begin{aligned} c(\mathbf{s}_{nt}, d_{nt}) &= G(\mathbf{s}_{nt}, d_{nt}) - savings(d_{nt}) \\ wealth_{nt+1} &= (1 + r_t)(wealth_{nt} + savings(d_{nt})) \\ wealth_{nt} &> 0 \end{aligned} \quad (6)$$

²⁰Some studies apply a two-step estimation approach and assume that μ_{nt} follows an autoregressive process (e.g. French (2005), French and Jones (2011)). However, these studies do not account for time-constant unobserved heterogeneity that may be correlated with the leisure preferences.

²¹Individuals are assumed to receive the expected wage if they are employed. From a theoretical point of view, this is justified if the transitory component of observed wages is only observed after the employment choice has been made and if individuals base their choices on expected wages. This abstraction from transitory wage risks simplifies the estimation of the model substantially and is of little importance for the simulation of the life cycle outcomes because transitory wage shocks even out over the life cycle. When computing gross labor earnings, I assume that individuals work the median number of hours, which is 40 in the sample.

²²When estimating a specification with $\log(wage_{nt})$ as a function of health status, the respective coefficient estimate is small and insignificant. It appears that individuals who are in bad health status either do not work or receive a wage according to their qualification. Of course, the qualification in terms of work experience may depend on past health outcomes. This is taken into account by the model.

where $c(\mathbf{s}_{nt}, d_{nt})$ is the level of consumption associated with state \mathbf{s}_{nt} and choice d_{nt} , and $G(\cdot)$ indicates net income by applying the rules and regulations of the German tax and transfer system and of the statutory pension insurance scheme.²³ I assume that the forward looking individuals neither expect future changes in the institutional framework nor do they expect a change in their economic situation that is due to finding a partner. $wealth_{nt}$ is period t 's net wealth, r_t is the real interest rate that is set to be 0.02 after taxes, and $savings(d_{nt})$ is the amount of savings associated with state \mathbf{s}_{nt} and choice d_{nt} . Retirees are assumed to dissave according to the value of an actuarially fair life annuity that could be bought with the accumulated wealth. A more detailed modeling of retirees' saving behavior is not necessary for my research questions. The first equation defines the possible levels of consumption in period t , the second equation describes the wealth accumulation process, and the third equation is a non-negativity constraint.

4.9 Unobserved heterogeneity and initial conditions

Following the approach of Heckman and Singer (1984), unobserved heterogeneity is accounted for semi-nonparametrically by allowing for a finite number of unobserved types $m \in 1, \dots, M$ (random effects). Each type comprises a fixed proportion of the individuals in the population. Hence, the individual-specific parameters α_{2n} , τ_n , and κ_n are assumed to be equal to the respective type-specific parameters α_{2m} , τ_m , and κ_m . The probability that individual n is of type m is given by

$$\pi_{mn} = \frac{\exp(\gamma_m \mathbf{z}_n)}{1 + \sum_{l=1}^{M-1} \exp(\gamma_l \mathbf{z}_n)}, \text{ for } m = 1, \dots, M - 1 \quad (7)$$

where γ_M is normalized to zero and $\sum_{m=1}^M \pi_{mn} = 1$. The vector \mathbf{z}_n contains initial observed health and employment status, and interaction terms between a variable indicating an age of 50 years or older in the first wave (including the individual) and initial observed health and employment status. The interaction terms account for individuals entering the sample at different ages. I deal with the initial condition problem (Heckman (1981)) by assuming that the unobserved true initial conditions

²³Since only marginal changes occurred to the institutional framework between 2005 and 2010, I apply the rules and regulations from the year 2005 to all survey years. This simplifies the estimation of the model and saves computational time because I do not have to estimate a different value function for each survey year.

(the process starts before the age of 40) are exogenous conditional on type. This follows the idea of Wooldridge (2005).²⁴ As opposed to an approach that assumes that the structural model can explain the distribution of the initial values of the state variables, this is computationally much less intense and does not rely on potentially unrealistic out-of-sample extrapolations (Aguirregabiria and Mira (2010)).

4.10 Choice probabilities and log-likelihood

Given the finite horizon of the individual's optimization problem, it can be solved recursively. The expected value function, $v_t(\mathbf{s}_{nt}, d_{nt})$, for period T is simply given by this period's expected utility flow:

$$v_T(\mathbf{s}_{nT}, d_{nT}) = u(\mathbf{s}_{nT}, d_{nT}) \quad (8)$$

By Bellman's principle of optimality, the individual's optimization problem can be written as a two-period problem for the other periods of time. It follows from the type 1 extreme value distribution of $\epsilon_{nt}(d_{nt})$ that the expected value function has a closed form solution (Rust (1987)):

$$v_t(\mathbf{s}_{nt}, d_{nt}) = u(\mathbf{s}_{nt}, d_{nt}) + p_{t+1}\beta \sum_{\mathbf{s}_{nt+1}} \log \left\{ \sum_{d_{nt+1} \in D(\mathbf{s}_{nt+1})} \exp(v_{t+1}(\mathbf{s}_{nt+1}, d_{nt+1})) \right\} q(\mathbf{s}_{nt+1} | \mathbf{s}_{nt}, d_{nt}) \quad (9)$$

The computation of the expected value functions for periods $t=65, \dots, T$ is comparatively simple because individual choices are only modeled for $t=40, \dots, 64$.

Rust (1987) shows that under the assumptions of additive separability and conditional independence, the conditional choice probabilities have a closed form solution (here: mixed logit probabilities):

$$Prob(d_{nt} | \mathbf{s}_{nt}) = \frac{\exp(v_t(\mathbf{s}_{nt}, d_{nt}))}{\sum_{j \in D(\mathbf{s}_{nt})} \exp(v_t(\mathbf{s}_{nt}, j))} \quad (10)$$

When computing choice probabilities, I take into account that the choice of employment is restricted with a probability of $1 - \phi_{gh}^{offer}$ or $1 - \phi_{bh}^{offer}$ for individuals who did not work in the previous period and with a probability of ϕ_{gh}^{sep} or ϕ_{bh}^{sep} for individuals who did

²⁴Akay (2011) performs various Monte Carlo experiments showing that such an approach works reasonably well for panel data sets of moderately long duration.

work in the previous period, where the respective rates differ by an individual's health status.

The expected value functions are only computed for a discretized state space in order to save computational time (Keane and Wolpin (1994)). As a consequence, interpolation methods must be used to approximate the functions at the observed values of the state variables. I resort to a cubic spline function - as recommended e.g. by Adda and Cooper (2003) for the estimation of dynamic models - to interpolate the expected value functions for net wealth, work experience, and years of education. For each of these variables, I define five grid points. My estimation results are insensitive to an increase in the number of these grid points. In total, the value function is computed for $1000 \times M$ grid points for each of the choices. Aside the points for net wealth, work experience, and years of education, the grid comprises points for the binary state variables region of residence, health status, lagged employment status and the unobserved types.

The log-likelihood function of the sample is given by

$$\sum_{n=1}^N \log \left\{ \sum_{m=1}^M \pi_{mn}(\gamma) \prod_{t=1}^T L_m(d_{nt}|\boldsymbol{\theta}_U, \boldsymbol{\phi}, \boldsymbol{\theta}_h, \boldsymbol{\theta}_w) L_m(health_{nt}|\boldsymbol{\theta}_h) L_m(wage_{nt}|\boldsymbol{\theta}_w) \right\} \quad (11)$$

where $L_m(d_{nt}|\boldsymbol{\theta}_U, \boldsymbol{\phi}, \boldsymbol{\theta}_h, \boldsymbol{\theta}_w)$ is the likelihood contribution of the observed choice d_{nt} of individual n in period t , if n is of type m . The likelihood contributions of the health process and wage equation are given by $L_m(health_{nt}|\boldsymbol{\theta}_h)$ and $L_m(wage_{nt}|\boldsymbol{\theta}_w)$, respectively.

5 FIML and extended EM algorithm

In principle, the model can be estimated by finding the maximum of the log-likelihood function. However, due to the non-separability of the log-likelihood function a step-wise maximization is impossible. Unless the starting values used for the optimization algorithm are very good, a direct maximization with respect to all parameters may involve considerable numerical problems and is computationally intense. For this reason, I resort to an extension of the EM algorithm to obtain good starting values for a subsequent FIML estimation. The extended EM algorithm has been proposed by Arcidiacono and Jones (2003) for the estimation of finite mixture models with time-constant unobserved heterogeneity. They show how this algorithm can facilitate the

estimation with little loss in efficiency by allowing for a sequential estimation of the parameters.

By Bayes rule, the conditional probability Π_{mn} that individual n is of type m , given the observed choices and the parameters that are contained in $\boldsymbol{\theta}_U, \boldsymbol{\phi}, \boldsymbol{\theta}_h, \boldsymbol{\theta}_w$, and $\boldsymbol{\gamma}$ (posterior type probability), is given by

$$\Pi_{mn} = \frac{\pi_{mn}(\boldsymbol{\gamma}) \prod_{t=1}^T L_m(d_{nt}|\boldsymbol{\theta}_U, \boldsymbol{\phi}, \boldsymbol{\theta}_h, \boldsymbol{\theta}_w) L_m(health_{nt}|\boldsymbol{\theta}_h) L_m(wage_{nt}|\boldsymbol{\theta}_w)}{\sum_{m=1}^M \pi_{mn}(\boldsymbol{\gamma}) \prod_{t=1}^T L_m(d_{nt}|\boldsymbol{\theta}_U, \boldsymbol{\phi}, \boldsymbol{\theta}_h, \boldsymbol{\theta}_w) L_m(health_{nt}|\boldsymbol{\theta}_h) L_m(wage_{nt}|\boldsymbol{\theta}_w)} \quad (12)$$

Using the conditional type probabilities, the following additively separable expected log-likelihood function can be derived:

$$\sum_{n=1}^N \sum_{m=1}^M \sum_{t=1}^T \Pi_{mn} (\log(L_m(d_{nt}|\boldsymbol{\theta}_U, \boldsymbol{\phi}, \boldsymbol{\theta}_h, \boldsymbol{\theta}_w)) + \log(L_m(health_{nt}|\boldsymbol{\theta}_h)) + \log(L_m(wage_{nt}|\boldsymbol{\theta}_w))) \quad (13)$$

The EM algorithm reintroduces additive separability at the maximization step. Starting with arbitrary initial values, the maximum of the log-likelihood function can be found by maximizing iteratively the expected log-likelihood function, then using the estimates of $\boldsymbol{\theta}_U, \boldsymbol{\phi}, \boldsymbol{\theta}_h$, and $\boldsymbol{\theta}_w$ to estimate $\boldsymbol{\gamma}$ by maximizing the log-likelihood function conditionally on these parameter estimates, and finally using all the estimated parameters for updating the posterior type probabilities. Subsequently, the expected log-likelihood function is maximized again. Iterating on these steps until convergence yields the maximum of the log-likelihood function (see Boyles (1983) and Wu (1983) for formal proofs). The additive separability of the expected log-likelihood function allows a sequential maximization. This is done by first estimating $\boldsymbol{\theta}_h$ and $\boldsymbol{\theta}_w$, and then taking these estimates as given in a maximization of the expected log-likelihood function with respect to $\boldsymbol{\theta}_U$. Arcidiacono and Jones (2003) show that such an extension of the EM algorithm produces consistent parameter estimates. While this estimation approach reduces the computational burden, the parameter estimates are inefficient and the estimation of standard errors is complicated because the computational time makes the use of bootstrapping methods unpractical. Therefore, I apply the extended EM algorithm to obtain good starting values for a subsequent FIML estimation. This also facilitates the computation of standard errors that can be derived from the inverse of the Hessian of the log-likelihood function at its maximum.

6 Estimation results and model fit

6.1 Parameter estimates

The extended EM algorithm gets close to convergence after a number of iterations that depends on the choice of starting values.²⁵ I abort the algorithm after 10 iterations and use the current trail values of the parameters as initial values in a FIML estimation. While the extended EM algorithm slows down when approaching convergence, the optimization algorithm that is used for the FIML estimation converges comparatively quickly when using good starting values. The log-likelihood at its maximum and at the trail values from the EM algorithm after 10 iterations differ only slightly (see table 2). Using bad starting values for the FIML approach usually results in non-convergence of the optimization algorithm. The model is estimated allowing for two unobserved types (M=2).²⁶ I did not achieve convergence for more than two unobserved types. Table 2 shows the parameter estimates, the current trail values of the extended EM algorithm after 10 iterations, and the starting values used for the extended EM algorithm. In the following, I shortly discuss the estimation results:

Utility function: The estimate of the consumption weight α_1 is reasonable and the coefficient of relative risk aversion, ρ , is estimated to be 1.17. This estimate of ρ is larger than the estimate of Rust and Phelan (1997), but smaller than the estimates of French (2005) and French and Jones (2011). Individuals exhibit unobserved heterogeneity in their leisure preferences that is captured by the type-specific parameter, α_{2m} . The parameter estimates for the value of leisure time are positive, but significant only for individuals of type 2.

Job offer and separation rates: The low estimated job offer rates indicate a high persistence of unemployment. This matches the small number of observed transitions from unemployment to employment in the data. Both the job offer and separation rates differ substantially by health status. A health shock is estimated to increase the labor market risks both by lowering the probability of a job offer and by raising the probability of a job separation.

²⁵The starting values are shown in table 2. Most starting values are set to be 0.1. The estimation results do not hinge on the choice of starting values.

²⁶Estimation takes about 11 hours on a standard laptop (i5-2430, 8gb ram, matlab 32 bit): about 8 hours for the 10 iterations of the EM algorithm and about 3 hours for the FIML estimation.

Table 2: Parameter estimates

	FIML		EM alg. (10 iterations)	Starting values
	Estimates	St.e.	Trail values	
Utility function:				
α_1 (consumption)	2.727	(0.2400)	2.619	0.1
ρ (crra)	1.165	(0.0271)	1.163	0.1
α_{21} (leisure, type 1)	0.326	(0.3504)	0.509	0.1
α_{22} (leisure, type 2)	1.388	(0.0892)	1.357	0.1
Job offer and separation rates:				
ϕ_{bh}^{sep} (separation, bad health)	0.100	(0.0216)	0.099	0.5
ϕ_{gh}^{sep} (separation, good health)	0.018	(0.0057)	0.018	0.5
ϕ_{bh}^{offer} (offer, bad health)	0.010	(0.0052)	0.010	0.5
ϕ_{gh}^{offer} (offer, good health)	0.074	(0.0145)	0.068	0.5
Wage equation:				
κ_1 (constant, type 1)	2.070	(0.0278)	2.075	2.5
κ_2 (constant, type 2)	1.633	(0.0225)	1.646	1.5
δ_1 (years of education / 10)	0.629	(0.0259)	0.608	0.5
δ_2 (work experience / 10)	0.053	(0.0074)	0.060	0.1
δ_3 (East Germany)	-0.308	(0.0106)	-0.306	0.1
σ_μ (standard deviation)	0.209	(0.0042)	0.209	0.1
Health process:				
τ_1 (constant, type 1)	-1.652	(0.4178)	-1.536	-1.5
τ_2 (constant, type 2)	-1.939	(0.3815)	-1.869	-1.5
ψ_1 ($health_{t-1}$)	3.368	(0.1399)	3.312	1.5
ψ_2 (years of education / 10)	0.739	(0.3010)	0.718	0.1
ψ_3 (age \geq 50)	-0.604	(0.1383)	-0.532	0.1
Prob. of type 1 (38.4 %):				
γ_0 (constant)	-1.651	(0.6745)	-1.829	0.1
γ_1 (initial health)	0.182	(0.4252)	0.219	0.1
γ_2 (initial health \times (age \geq 50))	-0.610	(0.5997)	-0.579	0.1
γ_3 (initial empl.)	1.437	(0.7235)	1.608	0.1
γ_4 (initial empl. \times (age \geq 50))	0.012	(0.5273)	-0.038	0.1
Estimation time	\approx 3 hours		\approx 8 hours	-
Log-likelihood	-4,237.7		-4,239.7	-11,977

Note: The indicated starting values are used for the extended EM algorithm, which is aborted after 10 iterations. Then, the current trial values of the parameters are used as starting values for the FIML estimation. At last, the standard errors are derived from the inverse of the Hessian of the log-likelihood function at its maximum. The sample consists of 594 independent and, in total, of 2,016 observations.

Wage equation: There is substantial unobserved heterogeneity in the earnings capacity of individuals that is captured by the type-specific constant κ_m and that is negatively correlated with the leisure preferences. As expected, years of education and work experience increase wages while residence in East Germany is associated with a lower wage. The latter finding reflects persistent differences in the level of wages between East and West Germany. The standard deviation of the normally distributed μ is estimated to be 0.21.

Health process: The coefficient on lagged health status, ψ_1 , points to considerable state dependence. Hence, individuals who experience a health shock tend to remain in bad health status. Years of education are associated positively with an individual's probability of good health. In line with the observed health pattern, an age of 50 years or older decreases the probability of good health.

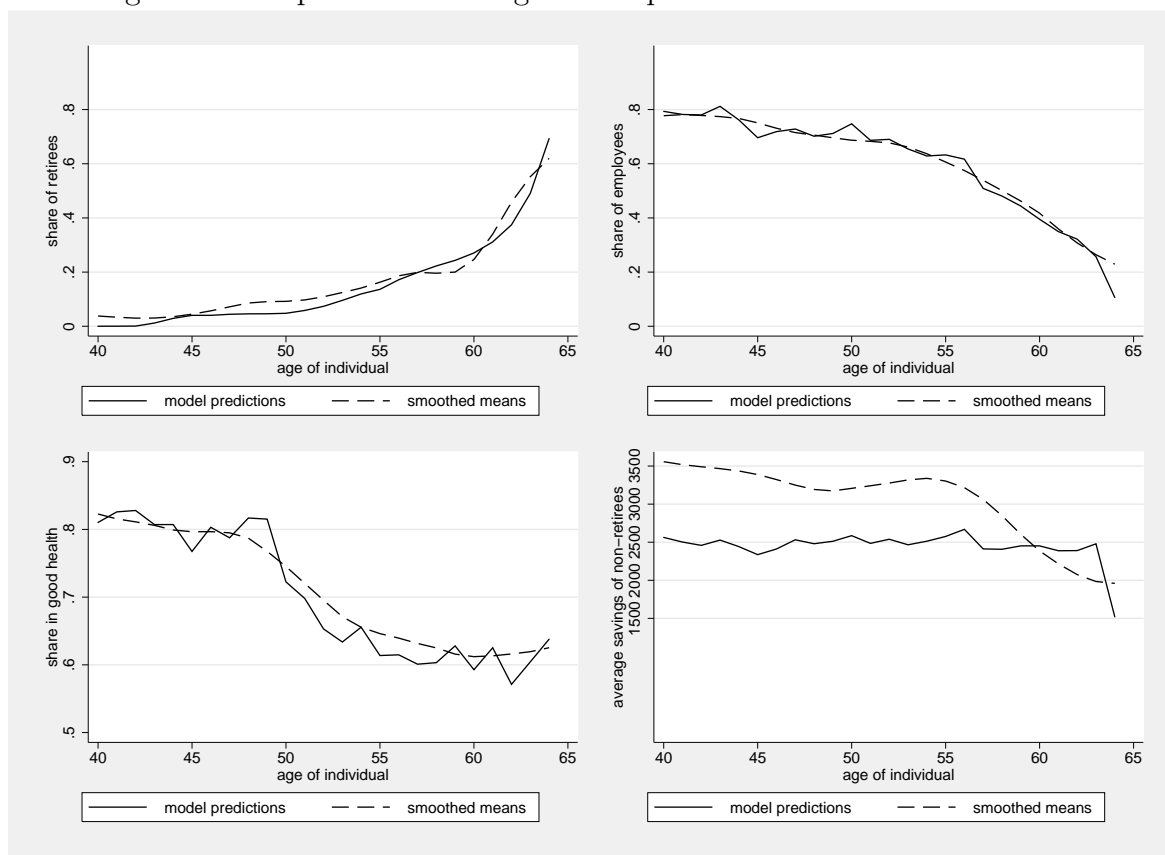
Type probabilities: The two unobserved types are predicted to comprise 38.4% and 61.6% of the population. Only the estimates for the constant and the coefficient on the initial observed employment status are significant, while the coefficient estimates on the other initial observed conditions are reasonable, but insignificant. The estimates suggest that individuals of type 1 are more likely than individuals of type 2 to enter the sample in employment.

6.2 Model fit

I check the model fit by making predictions for the probabilities of early retirement, employment, health status, and saving behavior for the individuals in my sample. I compare average predictions of the model by age with non-parametrically smoothed means. When computing average predictions for the retirement and employment choices, I take into account that retirement is modeled as an absorbing state and adjust the predictions such that they refer to the full population of retirees and non-retirees.²⁷ The smoothed means are computed on the basis of non-parametric local constant estimations of the association between the respective outcomes and age using the full sample of retirees and non-retirees. The local constant estimators thereby rely on a plugin es-

²⁷I compute the probability of employment as the probability of not having opted for early retirement in previous periods and choosing employment in the current period. The probability of being retired is the probability of either having opted for early retirement in one of the previous periods or opting for early retirement in the current period.

Figure 1: Comparison of average model predictions and smoothed means



estimator of the asymptotically optimal constant bandwidth (see Fan and Gijbels (1996), StataCorp (2009)) and an Epanechnikov kernel.

Figure 1 presents the model’s predictions and the smoothed means. It turns out that the average predictions fit the data reasonably well. However, I underpredict savings, which is a common problem of structural models (see e.g. van der Klaauw and Wolpin (2008), table 4). This is driven by the predicted choice probabilities for the higher saving categories and becomes relevant only for individuals with comparatively high income. As a consequence, an investigation of poverty risks should not be compromised. Since saving behavior merely affects how individuals distribute their consumption over the life cycle, the analysis of risks for lifetime consumption is unproblematic. Better predictions of the saving behavior presumably require the estimation of heterogeneous risk preferences. But, I did not achieve convergence of the optimization algorithm when allowing for additional type-specific coefficients for the coefficient of relative risk aversion, ρ , and the consumption weight, α_1 .

7 Policy Analysis

This section investigates the health-related risks of consumption and old age poverty. While the first subsection focuses on the health-related risks within the current institutional framework, the second subsection presents simulations that investigate means-tested minimum pension benefits as an insurance against old age poverty.

7.1 Health-related risks

Life cycle simulations are implemented for individuals by differing endowments at age 40, where endowments differ with respect to net wealth, work experience, and years of education. Individuals are assumed to be in good health status and to be employed in the year before they turn 40. The simulations are implemented under the assumption that individuals do not have additional private disability insurance. I simulate five scenarios where health shocks do or do not occur at different points in the life cycle. A comparison of simulated consumption paths between the scenarios sheds light on the health-related risks of consumption and old age poverty that are uninsured by the German social security system. In the first scenario, no health shock occurs (reference scenario). The second scenario follows the specification of the life cycle model such that health evolves stochastically according to the estimated health process. In the other three scenarios, a persistent health shock is assumed to occur at ages 60, 55, and 45, respectively, while no health shock occurs before these ages. A similar approach has been adopted by Haan and Myck (2009) when investigating health and labor market risks. In all scenarios, individuals behave as if health was evolving stochastically.

I simulate 5,000 life cycle paths for each of the varying endowments at age 40 in order to generate outcome distributions. The simulation of choices and transitions of the health status (for the second scenario) is done by taking quasi-random draws from the uniform distribution and by assuming that the model's parameters correspond to the point estimates from the FIML estimation. Analogously to the interpolation of the value function in the estimation of the model, I compute choice probabilities as well as income and consumption functions for a discretized state space and resort to a cubic spline function to interpolate these functions at the simulated values of the state variables. The transition probabilities of the health status are derived from the health

process. At the start of each of the simulations, the individual's unobserved type is determined by taking a draw from the uniform distribution. The distribution of types corresponds to the estimated distribution of types in the sample population. All state variables are carried forward between the periods.

I consider types of individuals in East and West Germany who are endowed at age 40 with a net wealth of either zero or €20,000, with either an employment history without any gaps or with a 5-year-period of non-employment, and having completed either 9, 13 or 18 years of education.²⁸ The investigation of such a grid of endowments gives an idea of the magnitude of risks and shows how these risks interrelate with the endowments.

7.1.1 Lifetime consumption

Expected consumption paths are computed by taking averages of the simulated consumption paths. Table 3 shows simulated losses in net present values (NPVs) of expected lifetime consumption at age 40 for scenarios 2-5 relative to scenario 1 (no health shock) that serves as reference scenario.²⁹ The difference in NPVs between scenario 2 (stochastic health) and the reference scenario 1 captures the magnitude of the health-related consumption risks. The differences between scenarios 3-5 and scenario 1 indicate the expected losses that are due to a persistent health shock at the ages 60, 55, and 45. The simulations suggest that expected health-related losses in lifetime consumption depend substantially on endowments at age 40 and range between 3% and 7%. The expected losses are larger for individuals without any net wealth at age 40 or with a lower level of education. Individuals who lack net wealth may have delayed retirement in the absence of a health shock. Lower education goes along with a higher probability of bad health status and lower opportunity costs of early retirement. The smaller expected losses in East Germany can be explained by the lower wages.

Expected losses can be severe if a health shock occurs at an early stage of the life cycle. For example, an individual in West Germany with a medium level of education (13 years), no gap in the employment history, and no net wealth at age 40 who

²⁸While 9 years correspond to the compulsory schooling, 13 years can be interpreted as either the completion of 10 years of schooling plus 3 more years of vocational training or the completion of an academic track school without any further professional training. 18 years usually correspond to 13 years of schooling in an academic track school plus 5 years of university education.

²⁹The NPVs of expected lifetime consumption at age 40 are presented in table 6 in the Appendix.

Table 3: Simulated loss of expected lifetime consumption at age 40

	Endowments at age 40			Losses in NPVs			
	Net wealth	5-year gap in empl.	Years of education	Stochastic health	Shock at age 60	Shock at age 55	Shock at age 45
West	20,000	no	9	5.9%	1.1%	3.9%	12.0%
West	20,000	yes	9	6.0%	1.2%	4.0%	13.0%
West	0	no	9	6.3%	1.2%	4.4%	13.5%
West	0	yes	9	6.3%	1.3%	4.5%	14.0%
West	20,000	no	13	6.0%	1.2%	4.9%	15.1%
West	20,000	yes	13	6.2%	1.4%	5.1%	16.3%
West	0	no	13	6.9%	1.5%	5.7%	18.1%
West	0	yes	13	6.9%	1.7%	5.9%	18.8%
West	20,000	no	18	3.8%	1.2%	4.5%	14.8%
West	20,000	yes	18	4.9%	1.6%	5.5%	20.6%
West	0	no	18	4.3%	1.4%	5.3%	17.9%
West	0	yes	18	5.1%	1.8%	6.3%	22.5%
East	20,000	no	9	4.3%	0.8%	2.9%	9.7%
East	20,000	yes	9	4.6%	0.9%	3.1%	10.5%
East	0	no	9	4.6%	0.9%	3.5%	10.4%
East	0	yes	9	4.5%	1.0%	3.6%	10.4%
East	20,000	no	13	4.1%	1.1%	3.7%	11.7%
East	20,000	yes	13	4.3%	1.1%	3.9%	12.9%
East	0	no	13	4.4%	1.2%	4.2%	13.0%
East	0	yes	13	4.4%	1.2%	4.4%	13.4%
East	20,000	no	18	3.3%	1.3%	4.8%	13.4%
East	20,000	yes	18	3.6%	1.5%	5.1%	15.7%
East	0	no	18	4.2%	1.6%	5.7%	17.7%
East	0	yes	18	4.3%	1.8%	5.9%	18.8%

Note: The simulated losses of expected lifetime consumption at age 40 are presented as reductions in net present values for scenarios 2-5 relative to scenario 1 (no health shock) that serves as reference scenario. The losses are simulated by endowments at age 40.

experiences a persistent health shock at age 45 faces a loss in the NPV of expected lifetime consumption of 18.1%. A persistent health shock at age 60 seems to induce comparatively small losses. In some cases such a health shock may even be financially beneficial because individuals who would have opted for early retirement anyway face a lower penalty on their pension benefits when being in bad health status. The simulations suggest that the German social security system may not sufficiently insure individuals against their health-related consumption risks. Of course, individuals can buy additional private disability insurance. These simulations merely show the limitations of the public insurance schemes.

Table 4: Simulated risk of old age poverty at age 40

	Endowments at age 40			Risk of old-age poverty				
	Net wealth	5-year gap in empl.	Years of education	No health shock	Stochastic health	Shock at age 60	Shock at age 55	Shock at age 45
West	20,000	no	9	39.0%	45.5%	42.3%	45.9%	49.1%
West	20,000	yes	9	45.9%	53.1%	48.5%	52.1%	60.0%
West	0	no	9	42.7%	51.6%	46.6%	51.8%	59.2%
West	0	yes	9	49.8%	58.2%	52.8%	57.6%	67.4%
West	20,000	no	13	4.9%	8.4%	5.7%	7.6%	13.2%
West	20,000	yes	13	11.4%	17.7%	12.9%	15.9%	26.5%
West	0	no	13	5.4%	12.0%	6.3%	8.9%	24.7%
West	0	yes	13	13.8%	23.4%	15.6%	20.9%	40.8%
West	20,000	no	18	3.3%	4.4%	3.3%	4.5%	7.7%
West	20,000	yes	18	4.9%	7.8%	5.7%	7.4%	18.1%
West	0	no	18	3.5%	5.2%	3.5%	5.0%	12.6%
West	0	yes	18	5.3%	9.2%	6.0%	8.5%	26.9%
East	20,000	no	9	63.1%	66.4%	63.9%	65.0%	71.2%
East	20,000	yes	9	64.3%	68.4%	65.1%	66.3%	76.2%
East	0	no	9	63.3%	67.6%	64.0%	65.7%	77.1%
East	0	yes	9	65.0%	70.5%	65.7%	68.1%	82.4%
East	20,000	no	13	49.9%	54.1%	51.6%	54.7%	60.9%
East	20,000	yes	13	54.8%	59.3%	56.5%	59.3%	69.9%
East	0	no	13	52.8%	58.3%	55.0%	59.0%	67.0%
East	0	yes	13	57.4%	62.6%	59.1%	63.1%	77.2%
East	20,000	no	18	6.1%	8.3%	6.8%	8.9%	15.0%
East	20,000	yes	18	13.6%	16.8%	15.3%	18.4%	33.2%
East	0	no	18	6.4%	11.1%	7.3%	10.6%	28.9%
East	0	yes	18	16.6%	22.7%	19.0%	25.1%	50.5%

Note: The simulated risk of old age poverty at age 40 is presented for scenarios 1-5. The differences between scenarios 2-5 and scenario 1 (no health shock) indicate health-related changes in the risk of old-age poverty. The risks are simulated by endowments at age 40.

7.1.2 Old age poverty

This subsection focuses on distributional outcomes and examines the health-related risk of old age poverty. I take the EU definition of relative poverty as a reference that defines individuals as being at the “risk of poverty” when receiving a net income below 60% of the median net equivalent income. This indicates a threshold value of €816 of monthly net income in 2005 (Statistisches Bundesamt (2008)).³⁰ In the following analysis, I define individuals as poor who experience a level of monthly consumption below €816. This is somewhat more conservative than the EU definition because monthly consumption after retirement may be higher than monthly income (as individuals con-

³⁰I use this threshold value because all nominal variables in my sample are adjusted to the purchasing power in 2005.

sume out of their accumulated wealth). Of course, the choice of the threshold value for poverty is a bit arbitrary. However, the overall pattern of the simulated risks of old age poverty and the health-related changes in these risks are insensitive to variations of the threshold value.

Table 4 presents the simulated risk of old age poverty by endowments at age 40. The differences between scenarios 2-5 and scenario 1 (no health shock) indicate health-related changes in the risk of old age poverty. For example, an individual with a medium level of education (13 years), no gap in the employment history, and no net wealth at age 40 who resides in West Germany faces a risk of old age poverty of 5.4% in the absence of health shocks, while the risk rises to 12.0% under stochastic health, and amounts to 24.7% when the individual experiences a persistent health shock at age 45. In East Germany, an individual with the same endowments faces risks of 52.8%, 58.3%, and 67.0% in the respective scenarios. The magnitude of the risks and health-related changes in these risks depend substantially on an individual's endowments at age 40 and may be sizable. The risk is greater in East than in West Germany and for individuals who lack net wealth or have experienced periods of non-employment. The findings suggest that there is a substantial risk of health-related old age poverty that is uninsured by the German social security system.

7.2 Means-tested minimum pension benefits

Given the discussed issue of health-related old age poverty, policy makers might consider a policy intervention. This subsection investigates a counterfactual reform of the statutory pension insurance scheme that insures individuals against the risk of old age poverty by introducing a minimum level of pension benefits at the - above defined - poverty line. Hence, the risk of old age poverty is reduced to zero (by definition). However, such a reform raises a concern about an increase in abuse of the early retirement option and a decline in average pension age that is due to an increased attractiveness of early retirement - in particular - for individuals with otherwise very low pension claims (moral hazard problem). In the model, cheating is taken into account in the sense that individuals who are in bad health status may opt for early retirement even though some of these individuals are not work incapacitated such that their employment choice is not restricted. There is also a countervailing effect because minimum pension benefits

reduce the risk of future pension claims by making them less dependent on labor market outcomes (lower bound). This induces an increase in the option value of remaining in the labor force.

I resort to an idea of Golosov and Tsyvinski (2006) who argue that disability benefits should be means-tested in order to make it more unattractive to falsely claim benefits. The rationale behind this idea is that individuals need savings to smooth their consumption, but the more they save the more they are penalized by the means test. This may prevent false claims of disability benefits if these benefits are not too generous relative to the wages that individuals can earn on the labor market. In the context of a pension scheme where the option of early retirement constitutes an insurance against work incapacity, this idea can be applied when introducing minimum pension benefits. A means test may reduce the potential increase in abuse that is due to the introduction of minimum pension benefits and ensure that only individuals who are in need benefit from the reform.

The scheme is set up as follows. If net pension benefits are below the minimum level (€816 of monthly consumption after retirement), net benefits are raised to the minimum level, but the increase is means-tested (as it is also the case for social assistance benefits).³¹ I use the model to simulate changes in expected retirement age by differing endowments at age 40. This is done analogously to the simulations in the previous subsection and under the assumption that the reform can be implemented without any increase in taxes or social security contributions (no budget neutrality). Given the level of means-tested social assistance benefits that can be claimed anyway (see section 3), any rise in taxes or social security contributions that is necessary to finance the reform is small and, hence, behavioral responses to this rise would be small as well. The approach avoids the problem of arbitrarily choosing a financing scheme, where behavioral responses may depend on this choice.

Table 5 presents the simulated changes in expected retirement age by endowments at age 40 that are induced by the reform under stochastic health (scenario 2). For comparison I also simulate a scheme of minimum pension benefits without a means test. The results indicate only a small decrease in individuals' expected retirement

³¹In the model, an individual's consumption is raised to the minimum level if the sum of pension benefits and dissavings (according to the value of an actuarially fair life annuity that could be bought with the accumulated wealth) is below the minimum level.

Table 5: Simulated changes in expected retirement age and expected lifetime consumption at age 40 through reform

	Endowments at age 40			$\Delta E(\text{retirement age})$		$\Delta NPV (\%)$	
	Net wealth	5-year gap in employment	Years of education	means test	no means test	means test	no means test
West	20,000	no	9	-0.14	-0.93	0.31%	1.92%
West	20,000	yes	9	-0.15	-1.83	1.65%	3.19%
West	0	no	9	-0.13	-0.78	0.96%	2.67%
West	0	yes	9	-0.25	-1.51	2.11%	3.63%
West	20,000	no	13	-0.24	-0.60	-1.13%	-2.30%
West	20,000	yes	13	-0.22	-1.12	-0.97%	-2.00%
West	0	no	13	-0.26	-0.52	-1.23%	-2.08%
West	0	yes	13	-0.17	-0.82	-0.83%	-1.40%
West	20,000	no	18	0.08	0.12	0.27%	0.27%
West	20,000	yes	18	0.02	-0.17	0.33%	0.78%
West	0	no	18	0.05	0.07	0.30%	0.32%
West	0	yes	18	-0.03	-0.20	0.28%	0.46%
East	20,000	no	9	-0.27	-2.45	3.60%	6.16%
East	20,000	yes	9	-0.37	-3.68	3.83%	7.99%
East	0	no	9	-0.39	-1.80	3.18%	5.09%
East	0	yes	9	-0.41	-2.49	3.94%	6.82%
East	20,000	no	13	-0.22	-1.44	2.37%	4.17%
East	20,000	yes	13	-0.28	-2.49	2.73%	4.87%
East	0	no	13	-0.29	-1.23	2.71%	4.40%
East	0	yes	13	-0.33	-1.88	2.96%	4.75%
East	20,000	no	18	-0.30	-0.94	-2.46%	-3.66%
East	20,000	yes	18	-0.20	-1.33	-1.29%	-1.71%
East	0	no	18	-0.33	-0.75	-2.49%	-3.53%
East	0	yes	18	-0.21	-0.99	-1.03%	-1.19%

Note: The changes in expected retirement age and net present values of expected lifetime consumption at age 40 that are induced through the introduction of minimum pension benefits are simulated under stochastic health (scenario 2) both with and without a means test. The simulations are performed by endowments at age 40.

age (between 0 and 0.4 years depending on endowments) if the minimum pension benefits are means-tested. The lower the net wealth at age 40 and the lower the level of education the larger the decrease. Even for individuals with a low level of education and no net wealth at age 40 the means test is highly relevant for expected retirement age. Without the means test, the decrease is substantial (between 0 and 3.7 years depending on endowments) suggesting a severe moral hazard problem. For some types of individuals at the upper end of the income distribution in West Germany, the reform is even predicted to induce a slight increase in expected retirement age that is due to the above described countervailing effect. Overall, the simulations indicate that a means test mitigates the moral hazard problem substantially.

8 Conclusion

This paper proposes a dynamic life cycle model of health risks, employment, early retirement, and wealth accumulation in order to analyze the health-related risks of consumption and old age poverty. In particular, the model includes a health process, the interaction between health and employment risks, and an explicit modeling of the German public insurance schemes, where unemployment insurance and early retirement constitute a partial insurance against work incapacity. Moreover, a policy simulation relates to an idea of Golosov and Tsyvinski (2006) and investigates means-tested minimum pension benefits as an insurance against old age poverty. The analysis focuses on single males. Presumably, the life cycle risks are smaller for couples because behavioral responses of the partner mitigate the effects of a health shock. Hence, the simulated risks may suggest an upper bound for couples.

I simulate scenarios where health shocks do or do not occur at different points in the life cycle for individuals with differing endowments at age 40. A comparison of simulated consumption paths between the scenarios sheds light on the health-related risks of consumption and old age poverty that are uninsured by the German social security system. The simulations suggest that expected health-related losses in lifetime consumption depend substantially on endowments and range between 3% and 7%. The expected losses are larger for individuals without any net wealth at age 40 or with a lower level of education and are smaller in East than in West Germany. Expected losses can be severe if a health shock occurs at an early stage of the life cycle. The simulations show the limitations of the public insurance schemes.

I also use the life cycle simulations to examine the health-related risk of old age poverty. The magnitude of the risk and health-related changes in this risk depend substantially on an individual's endowments at age 40 and may be sizable. The results of this analysis motivate the simulation of minimum pension benefits that insure individuals against the risk of old age poverty. While such a reform raises a concern about an increase in abuse of the early retirement option, the simulations indicate that a means test mitigates the moral hazard problem substantially. For a non-means-tested scheme, the simulations suggest a severe moral hazard problem. This finding may also apply to other countries with similar institutions.

9 Appendix

Table 6: NPVs of expected lifetime consumption at age 40

	Endowments at age 40			NPVs (€)				
	Net wealth	5-year gap in empl.	Years of education	No health shock	Stochastic health	Shock at age 60	Shock at age 55	Shock at age 45
West	20,000	no	9	353,420	332,410	349,510	339,610	310,960
West	20,000	yes	9	338,440	318,060	334,540	324,960	294,380
West	0	no	9	338,670	317,440	334,490	323,770	293,060
West	0	yes	9	324,860	304,530	320,760	310,260	279,500
West	20,000	no	13	482,280	453,550	476,490	458,730	409,380
West	20,000	yes	13	451,030	423,160	444,590	428,170	377,700
West	0	no	13	462,130	430,130	455,000	435,720	378,470
West	0	yes	13	428,440	398,960	421,260	403,190	347,730
West	20,000	no	18	578,540	556,580	571,530	552,320	492,900
West	20,000	yes	18	563,640	535,910	554,750	532,520	447,480
West	0	no	18	556,500	532,540	548,650	527,270	457,150
West	0	yes	18	543,100	515,170	533,330	509,020	420,670
East	20,000	no	9	283,880	271,580	281,670	275,550	256,370
East	20,000	yes	9	276,520	263,780	274,070	268,020	247,510
East	0	no	9	276,120	263,500	273,620	266,390	247,300
East	0	yes	9	268,300	256,280	265,600	258,780	240,460
East	20,000	no	13	326,060	312,570	322,590	314,060	287,880
East	20,000	yes	13	314,520	301,020	310,970	302,200	273,850
East	0	no	13	313,830	300,180	310,060	300,640	272,940
East	0	yes	13	303,120	289,930	299,380	289,800	262,410
East	20,000	no	18	470,520	455,080	464,400	448,100	407,470
East	20,000	yes	18	437,580	421,650	430,910	415,300	368,980
East	0	no	18	450,310	431,200	443,080	424,800	370,410
East	0	yes	18	415,010	397,230	407,660	390,440	336,900

Note: Expected lifetime consumption at age 40 is presented in terms of net present values for scenarios 1-5. The simulations are performed by endowments at age 40.

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