Longevity, Life-cycle Behavior and Pension Reform

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Abstract

How can public pension systems be reformed to ensure fiscal stability in the face of increasing life expectancy? To address this question, we use micro data to estimate a structural life-cycle model of individuals' employment, retirement and consumption decisions. We calculate that, in the case of Germany, an increase of 3.76 years in the pension age thresholds or a cut of 26.8% in the per-year value of public pension benefits would offset the fiscal consequences of the increase in life expectancy anticipated to occur over the next 40 years. On average, individuals value the increase in the pension age thresholds at 3.44% of baseline consumption, and are willing to forgo 8.51% of baseline consumption to avoid the cut in per-year pension value. The increase in the pension age thresholds makes 87.7% of individuals better-off, and generates large responses in labor supply and retirement behavior. However, the favorable effects of this reform depend on the availability of jobs for older individuals.

Keywords: Life Expectancy; Public Pension Reform; Retirement; Employment; Life-cycle Models; Consumption; Tax and Transfer System.

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1 Introduction

Over the last several decades the longevity of individuals living in the developed world has improved considerably and consistently, and this trend looks set to continue.[1] Such demographic change poses numerous social and economic challenges. Notably, many public pension systems, which are typically compulsory defined benefit schemes, are being strained by the greater pension demands concurrent with higher life expectancy. In response to this problem, an important political debate has arisen concerning how to reform public pension systems to address the fiscal demands created by improving longevity. This debate has focused on identifying effective ways of increasing the age-based eligibility requirements associated with public pension benefits. The policy response thus far has reflected this theme: e.g., Germany and the US have recently announced plans to gradually increase the full pensionable age, that is the age from which an individual may claim a non-reduced public pension, from 65 to 67 years of age.

We use a comprehensive dynamic structural model to understand the relationship between life expectancy, the public pension system and individuals' employment, retirement and consumption decisions over the life-cycle. We use Indirect Inference to estimate the model's parameters. Drawing on this framework, we are the first to analyze how changes in life expectancy affect optimal individual employment, retirement and consumption through the life-cycle. By looking at how individuals respond to changes in individual-specific and cohort-specific longevity, we break new ground by exploring the desirability of changes to the public pension system that are designed to cope with the fiscal challenges posed by increasing life expectancy. This paper, therefore, makes a novel contribution to the policy debate on how public pension systems can be reformed to deal effectively with the consequences for Government finances of increasing life expectancy.

Our structural life-cycle model includes stochastic job offers, involuntary separations, saving opportunities and borrowing constraints, early retirement possibilities, unobserved heterogeneity in preferences, employment opportunities and wages, and detailed specifications of the tax and transfer systems. Moreover, the modeling approach naturally allows life expectancy and the public pension system to influence the decisions of forward-looking individuals planning for retirement. This methodology is ideally suited to quantifying the effect of life expectancy on behavior and to exploring the consequences of reductions in public pension generosity. By considering the interplay between life expectancy and public pension reform when individuals may adjust employment, retirement and consumption behavior, we expand on previous applications of structural life-cycle models. In particular, our paper builds on several previous studies that have used life-cycle models to investigate the effects of public pension systems on labor supply, retirement and consumption decisions (e.g., Casanova, 2010, French, 2005, French and Jones, 2012, Gustman and Steinmeier, 1986, Gustman and Steinmeier, 2005, Heyma, 2004, Jiménez-Martín and Sanchez Martín, 2007, Rust and Phelan, 1997, and van der Klaauw and Wolpin, 2008) and on work that developed structural life-cycle models in which individuals choose jointly consumption and labor supply

[1]E.g., Oeppen and Vaupel (2002) show that over the last 150 years life expectancy at birth in the developed world has increased at a rate of 2.5 years per decade, and argue that this linear trend is likely to continue.

(e.g., Imai and Keane, 2004, and Keane and Wolpin, 2001).[2] Our paper is also related to a small literature that looks at the effect of life expectancy on the saving decision alone (see Brown, 2001, De Nardi et al., 2010, Gan et al., 2004, and Hurd, 1989).

We implement our model in the context of Germany, a country with a compulsory pay-as-you-go defined benefit public pension system that displays many similarities to Social Security in the United States. Couching the analysis in the context of Germany allows us to exploit a unique pattern of variation in the evolution of demographic group-specific life expectancy that arose due to events following German reunification in 1990. Specifically, drawing on variation between demographic groups in the extent of improvements in life expectancy, we demonstrate that the estimated model predicts the observed relationship between life expectancy and retirement. This suggests that our model provides a sound basis for counterfactual policy simulations that explore the effect of life expectancy on employment, retirement and consumption behavior.

In terms of data sources, we obtain projections of age-specific life expectancies by cohort, region and gender from the Human Mortality Database for Germany. Data on life expectancy are combined with a sample of older individuals taken from the German Socio-Economic Panel and covering the years 1991 - 2007. In addition to replicating the observed relationship between life expectancy and retirement behavior as discussed above, the fitted model is able to reproduce the distribution of observed wages, the age profile of wealth and the age-specific rates of transitions between employment and unemployment.

The leading results of counterfactual policy simulations based on the estimated structural life-cycle model are twofold. First, in response to an increase in life expectancy we find individuals work more and postpone retirement, thereby increasing public pension benefits for their now longer retirement periods. The increase in Government revenue generated by the increase in employment is dwarfed by the increase in public pension demands. Quantitatively, the 6.4 year increase in age 65 life expectancy anticipated to occur over the next 40 years leads average net Government revenue per person, summed over the life-cycle starting at age 40 years and continuing until death, to decrease by approximately 66095 Euros.

Second, we demonstrate striking differences in behavioral and welfare responses to policies that involve revenue-equivalent reductions in public pension generosity. We calculate that the fiscal consequences of the 6.4 year increase in age 65 life expectancy anticipated to occur over the next 40 years can be offset by either an increase of 3.76 years in all pension age thresholds, including the full pensionable age, or a cut of 26.8% in the per-year value of public pension benefits. The increase in the pension age thresholds elicits a marked increase in the employment rate. However, this favorable employment response depends crucially on older individuals' employment opportunities; in the extreme, with very low employment opportunities for older individuals, it is impossible to offset the fiscal cost of an increase life expectancy purely by increasing the pension age thresholds. Meanwhile, the revenue-equivalent cut in the per-year value of public pension benefits has little impact on employment outcomes. In terms of welfare, on average individuals value the increase in pension age thresholds at 3.44% of baseline consumption, and are willing

[2] A largely separate literature presents empirical evidence from micro data of a direct effect of pension rights on retirement decisions (e.g., Blau, 1994, Blundell et al., 2002, Disney and Smith, 2002, French and Jones, 2011, Friedberg, 2000, and Friedberg and Webb, 2005). Blöndal and Scarpetta (1997) and Gruber and Wise (1998) demonstrate a similar relationship at the macro level. Gruber and Wise (2004, 2007) survey the micro and macro evidence.

to forgo 8.51% of baseline consumption to avoid the cut in per-year pension value. To further inform on the nature of the optimal public pension system, we compare the welfare implications of a more extensive set of revenue-equivalent public pension reforms. Relative to the current system, the public pension system that individual value most highly is less generous to high-wage high-experience individuals but involves stronger labor supply incentives for those with, *ex ante*, the lowest propensity to work.

This paper proceeds as follows. Section 2 outlines our life-cycle model. Section 3 describes our data sources. Section 4 provides an overview the estimation methodology, presents our structural parameter estimates and demonstrates the model's goodness of fit. Section 5 discusses the results of counterfactual policy simulations. Section 6 concludes.

2 Model

2.1 Overview

To examine the impact of life expectancy on life-cycle behavior and to explore the effectiveness of public pension reforms, we develop a rich dynamic structural model of individual's employment, retirement and consumption decisions over the life-cycle. We propose a discrete-time finite-horizon model. Each quarter, i.e., every three months, an individual chooses his or her current labor market state and current consumption.[3] We distinguish three labor market states: full-time work (f); unemployment (u); and retirement (r).[4] Retirement is assumed to be an absorbing state, and all non-working non-retired individuals are categorized as unemployed. In our model, therefore, an unemployed individual may be a participant or a non-participant in the labor force. We discuss our definition of the employment and retirement states in Section 3.1. Experience is accumulated endogenously: each quarter of full-time work adds 0.25 of a year to an individual's stock of experience, and accumulated experience impacts on wages and on unemployment and pension benefits.

Individuals are indexed by $i = 1, ..., N$, and age, measured in quarters of a year, is indexed by t.[5] The maximum possible age to which an individual can live is denoted by $\overline{T}$. We follow the life tables and use $\overline{T} = 110$ years. We focus on the employment, retirement and consumption behavior of individuals aged 40 years and above. Following De Nardi et al. (2010), in the interest of ensuring our empirical analysis captures precisely the relevant institutional and environmental factors, we only study those individuals who reside in single-adult households and who do not have dependent children.[6] Single-adult households account for around 30% of all households in which the household head is aged 40-65 years. We do not suggest that single individuals are

[3]Quarterly decision making allows accurate modeling of the Unemployment Insurance system.

[4]Full-time work is 39 hours of work per week. This is the median hours of work of the sampled individuals.

[5]To improve readability we do not introduce further subscripts to index specific cohorts or years: cohort information is specific to the individual, and together with age information, the year is thereby defined.

[6]Older non-retired individuals constitute the demographic group for which we expect behavior to be most sensitive to life expectancy and the design of the pension system. Indeed, previous work has shown that the labor supply and retirement decisions of older, yet working age, individuals are relatively elastic with respect to income (e.g., Gruber and Wise, 2004, Haveman et al., 1991, and Lalive et al., 2006).

representative of the full population.[7] However, as discussed in the conclusion, we believe our findings for singles are at least indicative of the likely results for other demographic groups.

Each period, an individual enjoys a flow of utility that depends on current consumption, $c_{i,t}$, current leisure and individual-specific preference shifters. We use $U_{i,t}(c_{i,t}, j)$ for $j = f, u, r$ to denote individual i's age t flow utility from employment and retirement state j. Following Low et al. (2010), we adopt the following constant relative risk aversion (CRRA) specification for preferences:

$$U_{i,t}(c_{i,t}, f) = \beta \frac{(c_{i,t}(1-\eta_i))^{1-\rho}}{1-\rho} + \varepsilon_{i,f,t}, \quad (1)$$

$$U_{i,t}(c_{i,t}, j) = \beta \frac{c_{i,t}^{1-\rho}}{1-\rho} + \varepsilon_{i,j,t} \text{ for } j = u, r. \quad (2)$$

In equations (1) and (2) ρ is the coefficient of relative risk aversion, and η_i describes the complementarity between consumption and leisure. We impose $\eta_i \in [0, 1)$, and thus we can interpret η_i as the share of consumption necessary to compensate individual i for the disutility of working. We allow unobserved heterogeneity in the complementarity between leisure and consumption by assuming that $\eta_i|\chi_i \sim N(\mu_\eta, \sigma_\eta^2)$ and truncated to lie in [0,0.999], where χ_i denotes the individual's observed characteristics at the time of labor market entry. The unobservables $\varepsilon_{i,f,t}$, $\varepsilon_{i,u,t}$, and $\varepsilon_{i,r,t}$ represent transient individual-specific preference shifters while β determines the importance of consumption and leisure in preferences, relative to the transient individual-specific unobservables. These unobservable terms are assumed to be serially and mutually independent, and distributed according to a type-I extreme value distribution. Such a formulation allows us to obtain analytic expressions for subcomponents of the value function; Appendix A provides further details. Our specification of the flow utilities implies that retired and unemployed individuals have the same preferences for leisure and consumption (French, 2005, and van der Klaauw and Wolpin, 2008, adopt similar specifications). However, the value functions derived below in equations (10)-(14) capture the relevant differences in life-cycle payoffs from unemployment and retirement. For example, the value function for an unemployed individual depends on the job offer rate and the expected flow utilities from future employment whereas for a retired individual the value function depends only on the expected flow utilities in retirement.

Current consumption is the sum of current net income and current dissaving. Current net income, in turn, depends on gross labor income, interest income from wealth, and the contemporaneous tax, transfer and pension systems. The pension system, which is of particular relevance for our analysis, is the subject of Section 2.4. In terms of the tax and transfer systems, our model includes income tax deductions, Social Security Contributions, and the two leading forms of out-of-work transfers: Social Assistance; and Unemployment Insurance. Social Assistance is a means-tested benefit designed to ensure a universal minimum income, irrespective of past employment or earnings. Unemployment Insurance meanwhile replaces a fraction of previous net earnings and is paid for an entitlement period determined by an individual's age and recent employment history (see Haan and Prowse, 2010, for further details on the Unemployment In-

[7] Our calculations, based on the German Socio-Economic Panel for 1991-2007, show single women aged 40 years are 9.4 percentage points more likely to be employed than cohabiting women of the same age, while the corresponding difference for men is -8.5 percentage points. By age 60 years these differences narrow to 6.6 percentage points for women and -0.5 of a percentage point for men.

surance system during the sample period). Our model therefore captures the possibility for an unemployed individual to receive Social Assistance or Unemployment Insurance, or some combination thereof. Appendix B provides further details about the tax and transfer systems. When implementing the model we make the standard assumption that individuals expect the current year-specific tax and transfer systems to persist into future years (see Keane, 2011, for discussion of this approach). This assumption is justified here because the reforms to the tax and transfer systems that occurred during the sample period, e.g., an income tax reform in 2000 and a reform of Unemployment Insurance in 1997, were announced at short notice or the timing was changed.

Individuals are forward-looking and each period make employment, retirement and consumption decisions to maximize the discounted expected value of future utility. An individual's age t optimization problem is given by

$$\max_{d,c} \mathrm{E}_t \sum_{s=t}^{\overline{T}} \delta^{s-t} k_{i,s,t} U_{i,s}(c_{i,s}, d_{i,s}). \tag{3}$$

In the above $d_{i,t} \in \{f, u, r\}$ is a categorial variable that codes the individual's age t labor supply and retirement behavior. The variable d details the individual's employment and retirement behavior in each remaining period of the individual's life. Similarly, c is a vector that describes the individual's consumption choice in each remaining period of the individual's life. The operator E_t is an expectation conditional on the individual's age t information set. Payoffs occurring in the future are discounted due to subjective time discounting and mortality risk; $\delta \in [0, 1]$ is the subjective time discount factor, and $k_{i,s,t}$ is the probability of the individual surviving until age s conditional on being aged t. The inclusion of survival probabilities in the objective function reflects the dependence of life-cycle utility on life expectancy. We assume the individual is informed about his or her individual-specific survival probabilities. This assumption is consistent with Gan et al. (2004) and Hurd and McGarry (2002) who show individual-level subjective survival probabilities concur with the life tables, and are predictive of actual mortality.

We follow, *inter alios*, De Nardi et al. (2010), van der Klaauw and Wolpin (2008) and Rust and Phelan (1997) and allow individual-level heterogeneity in life expectancy. Specifically, we allow variation in survival rates, and therefore life expectancy, according to gender and region of residence. Additionally, extending on previous studies, we allow life expectancy to be cohort-specific and therefore we capture the sizable increases in life expectancy that occurred during the sample period. In Section 3.2 we discuss the empirical relevance and statistical advantages associated with our relatively rich approach to modeling life expectancy.

The optimization process is subject to an intertemporal budget constraint. In addition, behavior is subject to constraints on borrowing and on the availability of employment and retirement opportunities. We describe below: i) the nature of employment opportunities; ii) the composition of gross wage income; iii) the public pension system; iv) borrowing constraints, consumption possibilities and the intertemporal budget constraint; and v) the optimal arrangement of employment, retirement and consumption over the life-cycle.

2.2 Employment Opportunities

Behavior is constrained by the availability of employment opportunities. These constraints mean that employment responses can be small, despite strong financial incentives to work.

At the beginning of each period an unemployed individual receives a job offer with probability $\Theta_{i,t}$. Upon receipt of a job offer, the individual observes the current gross wage, $w_{i,t}$, associated with the job opportunity. The age t job offer probability takes the form

$$\Theta_{i,t} = \Phi(\lambda_\Theta x_{i,t} + \mu_i^\Theta). \tag{4}$$

Here and henceforth $\Phi()$ denotes the cumulative distribution function of a standard normal random variable. We allow the job offer probability to depend on age, region of residence and health status. Variables measuring these characteristics are included in $x_{i,t}$. λ_Θ is a suitably dimensioned parameter vector. Finally, μ_i^Θ represents unobserved individual characteristics. An individual in receipt of a job offer has the option of moving into employment in the current period. With probability $(1 - \Theta_{i,t})$ a previously unemployed individual does not receive a job offer at age t, in which case a transition into employment in the current period is impossible.

Similarly, at the beginning of each period an employed individual experiences an involuntary separation with probability $\Gamma_{i,t}$. The age t probability of an involuntary separation takes the form

$$\Gamma_{i,t} = \Phi(\lambda_\Gamma x_{i,t} + \mu_i^\Gamma), \tag{5}$$

where λ_Γ is a suitably dimensioned parameter vector and μ_i^Γ is an unobserved individual effect. An individual subject to an involuntary separation does not have the option of remaining in employment in the current period. With probability $(1 - \Gamma_{i,t})$ a previously employed individual does not experience an involuntary separation and has the opportunity to stay in employment and to be paid new gross wage, $w_{i,t}$.

We interpret the unobserved individual effects in the job offer and involuntary separation probabilities as permanent unobserved individual characteristics that impact an individual's ability to find or keep a job. These unobservables are assumed to be assigned to an individual at the time of first labor market entry, and to have a joint distribution given by $[\mu_i^\Theta, \mu_i^\Gamma]|\chi_i \sim N(0, \Sigma^\mu)$.

2.3 Gross Wage Offers

As discussed below in Section 2.4, gross wages are the primary determinant of public pension benefits. For the model to assign accurately pension benefits it is critical that we capture the cross-sectional and intertemporal variation in wages. The recent literature on earnings dynamics, e.g., Meghir and Pistaferri (2004) and Altonji et al. (2009), has shown the importance of permanent, transitory and autocorrelated unobservables in wages. Motivated by these findings, we adopt the following rich specification for the wage process

$$\log(w_{i,t}) = \lambda z_{i,t} + \alpha_i + \tau_{i,t} + \upsilon_{i,t}. \tag{6}$$

In the above, $z_{i,t}$ contains observed individual characteristics including education, region of residence and experience, and λ is a suitably dimensioned parameter vector. The inclusion of experience is important here because it captures the endogenous accumulation of experience-based human capital (e.g., Eckstein and Wolpin, 1989, and Keane and Wolpin, 1997).

In (6), α_i is a permanent individual-specific random effect, representing ability or skill. We take α_i to be assigned to an individual at the time of first labor market entry and assume $\alpha_i|\chi_i \sim N(0, \sigma_\alpha^2)$. $\tau_{i,t}$ is a persistent unobservable, which we interpret as an employer-employee match-specific productivity effect. For an individual who was employed in the previous period, $\tau_{i,t}$ keeps the same value as in the previous period with probability Π, and with probability $(1 - \Pi)$ the individual's match-specific productivity is subject to a shock. In the latter case, the individual receives a new match-specific productivity shock $\tau_{i,t}|\varphi_{i,t} \sim N(0, \sigma_\tau^2)$, where $\varphi_{i,t}$ denotes the individual's age t characteristics, including previous labor market outcomes and previous unobserved characteristics. An individual who was unemployed in the previous period and who is in receipt of a job offer in the current period receives a new match-specific productivity shock $\tau_{i,t}|\varphi_{i,t} \sim N(0, \sigma_\tau^2)$. In contrast to Low et al. (2010), we do not model or observe transitions between employers; we identify Π and σ_τ^2 from the persistence in individual-specific wage observations (see Table 7). Finally, $\upsilon_{i,t}|\varphi_{i,t} \sim N(0, \sigma_\upsilon^2)$ is a transitory wage shock. The parameters of the wage process are estimated jointly with the other structural parameters. The three unobserved components of wages are assumed to be mutually independent and independent of the unobservables that affect preferences and the job offer and involuntary separation probabilities. However, we fully account for selection into employment on the basis of wages (see Appendix C.2).

2.4 Public Pension System

German public pension benefits reflect employment and earnings outcomes prior to retirement. We provide below a summary of the relevant aspects of the public pension system. Unless noted otherwise, the model is estimated with the described specification of pension benefits.[8]

2.4.1 Accumulation of Pension Entitlement (Pension Points)

Public pension benefits in Germany are linked to an individual's labor market history via a quantity we refer to as "weighted pension points". An individual accumulates one pension point for every year of employment. Up to a cap of roughly 2, a pension point accumulated by an employed individual is weighed by the ratio of his or her current gross wage relative to the current mean gross wage. An individual also accumulates one pension point for every year of Unemployment Insurance-eligible unemployment. Up to a cap of roughly 1.6, a pension point accumulated by an unemployed individual is weighed by 0.8 times the ratio of his or her most recent gross wage relative to the current mean gross wage.[9]

[8] Börsch-Supan and Wilke (2004) note that public pension benefits in Germany account for approximately 85% of pension income, while individual and occupational pensions account for 10% and 5% of pension income respectively. We refrain from modeling individual and occupational pensions. Instead, we assume the provision for private saving afforded by our model approximates the saving opportunities offered by individual and occupational pensions.

[9] The German legislation specifies that one parent, normally the mother, be credited with one pension point for each child born before 1992 and three pension points for each child born thereafter. In the empirical implementation, we credit all women who had at least one child prior to entering the sample with 3 additional pension points. The German legislation further specifies that individuals may be awarded pension points for vocational training, university education, military or community service, and provision of care to relatives. We neglect these additional pension points.

2.4.2 Public Pension Value and Access to Public Pension Benefits

At the full pensionable age, which is 65 years for the retirees in our sample, an individual can retire and receive a publicly-provided pension with a value proportional to the sum of weighted pension points accumulated prior to retirement. The German public pension system is relatively generous: according to Börsch-Supan and Schnabel (1998), in 1998 public pension benefits provided a replacement rate of around 70% of pre-retirement net earnings for an individual retiring at the full pensionable age with 45 years of working experience and average life-time earnings. The proportionality factor used to convert weighted pension points into a pension value has varied over time, primarily to keep pace with wage inflation (see Table 8 in Haan and Prowse, 2011). We implement the model using the applicable year-specific proportionality factors. The sum of interest income from wealth and around 30% of income from pension benefits, less the tax-free allowance, is subject to income tax. As in French (2005), the forward-looking individuals in our model anticipate the taxation of pension benefits and adjust behavior accordingly.

Our model recognizes that early retirement may be possible on grounds of gender or working history. When implementing the model we impose the year-specific and cohort-specific gender-based and working history-based early retirement rules in effect at the time behavior is observed. Our implementation thus reflects that the early retirement rules have varied over time and that individuals in different cohorts may face different early retirement rules. We provide here a summary of the early retirement rules. Prior to 1999 women aged 60 and above and all those aged 63 and above with at least 35 years of experience were able to retire and receive a "non-reduced pension", i.e., a pension with value proportional to number of weighted pension points accumulated by the date of retirement, with the proportionality factor being the same as for individuals retiring at the full pensionable age; conditional on pension entitlement, there was no penalty for early retirement. Legislative reforms in 1992 and 1999 removed these provisions and introduced the right to early retirement from age 60 years with a reduced public pension for individuals with 35 years of experience. The value of the reduced public pension is obtained by applying a penalty of 3.6% to the non-reduced pension for every year that the individual's age upon retirement is below the full pensionable. The phase-in of the 1992 legislation commenced in 1997, and the combined 1992 and 1999 reforms will be fully effective by 2017. See Bonin (2009) for further details.[10]

In line the with institutional rules, we also allow early retirement due to disability. The rules that determine eligibility for public pension benefits on the grounds of disability are complex and the operationalization of these rules has inevitably been somewhat subjective. For the purpose of implementing our model, we assume that individual i has a probability $\Upsilon_{i,t}$ of being eligible for early retirement on the grounds of disability. The age t probability of being eligible for public pension benefits on the grounds of disability is as follows

$$\Upsilon_{i,t} = \Phi(\lambda_\Upsilon q_{i,t}), \tag{7}$$

where $q_{i,t}$ contains variables that measure the individual's gender and health status, and λ_Υ is a

[10] In principle, it is possible to work and receive pension benefits, but prior to the full pensionable age any labor income above a relatively low earnings limit is subject to an earnings test. Employment among individuals who receive public pension benefits is extremely rare in Germany (see Börsch-Supan and Schnabel, 1998) and therefore does not feature in our model.

suitably-idimensioned parameter vector. An individual retiring on the grounds of disability before age 60 receives the non-reduced pension that would be payable at age 60 if the individual worked continually until this age and maintained his or her current position in the earnings distribution. Additionally, individuals aged over 60 years who are able to demonstrate sufficiently poor health can take early retirement and thus claim public pension benefits. Prior to 2002, such individuals received a non-reduced public pension. More recently, the non-reduced public pension has only been available to individuals with sufficiently poor health aged 63 years or over at the date of retirement. Meanwhile, those entering early retirement due to disability between the ages of 60 and 63 years have received a reduced public pension. Again, the value of the reduced public pension is obtained by applying a penalty to the non-reduced pension of 3.6% for every year that the individual's age upon retirement is below the full pensionable age.

In principle, it is possible to work beyond the full pensionable age. In fact, the financial incentives to continue working are rather high: employed individuals continue to accumulate pension points after the full pensionable age, and the proportionality factor used to convert weighted pension points into a pension increases by 6% for every year retirement is postponed beyond the full pensionable age. However, all employment contracts end by default when the employee reaches the full pensionable age, and therefore employment beyond the full pensionable age requires renegotiation of the terms of employment. Consistent with this, in our SOEP sample fewer than 1% of those aged at or above the full pensionable age of 65 years are employed. When estimating the model, therefore, we do not permit employment at age 65 years or above. However, in the policy analysis presented in Section 5 we allow employment until age 80 years, irrespective of the policy parameters and irrespective of life expectancy, and we impose the correct pension rules on any individual who chooses to work beyond the full pensionable age.

2.4.3 Expectations about Future Public Pension Systems

Following most previous work that uses structural life-cycle models to understand the behavioral implications of pension systems, we assume that individuals expect the current year-specific and cohort-specific rules that define the public pension system to be maintained indefinitely. We argue this assumption is justified here because the pension reforms that occurred during the sample period either had highly uncertain implementation schedules, i.e., the timing was changed, or were cohort-specific changes that impacted mostly on individuals younger than 40 years.[11]

The most important year-specific change in the public pension system during the sample period was the introduction of the "sustainability factor" in 2005. The sustainability factor affects the above-discussed proportionality factor, which links weighted pension points to pension benefits. Specifically, the sustainability factor depends on the ratio of pension contributors to pension recipients, and the value of pension benefits is increasing in the sustainability factor. The eventual introduction of the sustainability factor followed an extended period of uncertainty over the timing and precise nature of the reform. In the mid-1990s plans to implement a slightly different version of the sustainability factor was announced, but never implemented due to a change of Government in 1998. Finally, in 2005 the sustainability factor was introduced with almost immediate effect. Given the vast uncertainty surrounding this policy it seems reasonable to

[11] The net value of pension benefits is affected by the tax and transfer systems as well as the pension system. As justified above in Section 2.1, we assume individuals expect the current tax and transfer systems to be maintained.

assume that prior to 2005 individuals did not expect the sustainability factor to be implemented.

For the years 2005-2007 the sustainability factor enters the model as unanticipated adjustments in the year-specific proportionality factor that links pension points to pension benefits. The magnitudes of these adjustments are taken directly from the year-specific pension rules, i.e., we plug into the model the legislatively-specified proportionality factors, and thus we do not use the model to solve for the sustainability factor. We therefore treat the sustainability factor in the same way as other year-to-year changes in the proportionality factor (see Section 2.4.2). Our modeling assumptions piertaining to the sustainability factor are supported by a robustness check in which we show that our estimates of the key preference parameters are robust to excluding observations from the years 2005-2007 (see footnote 22).

Regarding cohort-specific changes in the public pension system, the time frame of our study coincides partly with the phase-in period for an increase in the full pensionable age from 65 to 67 years and with changes in the eligibility requirements for early retirement. Importantly, as we restrict attention to individuals aged 40 years and above, the full pensionable age and the access rules for early retirement did not change at the individual level for the vast majority of the individuals under study. It is therefore realistic to assume the individuals under study expect the full pensionable age, and access rules for early retirement currently applicable to their particular birth cohort to remain in place.

2.5 Borrowing, Consumption and the Intertemporal Budget Constraint

Individuals may save and borrow. Wealth ($W_{i,t}$) here refers to an individual's private wealth holdings, and therefore excludes the value of any entitlements to the public pension or other social programs. The individual faces borrowing constraints which restrict wealth to be non-negative, that is $W_{i,t} \geq 0$. This assumption, which follows French (2005) and Low et al. (2010), reflects that borrowing typically requires collateral and that individuals are unable to borrow against future earnings or future Unemployment Insurance, Social Assistance or public pension benefits.

Subject to the above-described borrowing constraints, each period a non-retired individual chooses a consumption level, $c_{i,t}$. Quarter-by-quarter wealth accumulation for a non-retired individual is described by the following intertemporal budget constraint

$$W_{i,t+0.25} = W_{i,t} + G(w_{i,t}, rW_{i,t}, j, TT_{i,t}) - c_{i,t}, \tag{8}$$

where $G()$ denotes the individual's age t net income. Net income is a function of the wage rate, $w_{i,t}$, income from wealth, $rW_{i,t}$ where r is the interest rate, employment status, $j = f$ or u, and the tax and transfer rules in effect when the individual is age t, $TT_{i,t}$. In contrast to the models of retirement behavior developed by, e.g., French and Jones (2011) and Rust and Phelan (1997), we do not include medical expenses. This is reasonable because Germany has a universal health-care system.

We assume that once retired an individual dissaves an amount equal to the actuarially fair annuity value of accumulated wealth. The per-period consumption enjoyed by an individual who retires at age t thus given by

$$c_{i,t} = m_{i,r,t} + a_{i,t}, \tag{9}$$

where $m_{i,r,t}$ denotes the per-period net value of pension and transfer income and $a_{i,t}$ denotes per-period annuity value of wealth. This specification captures the primary intertemporal incentives important for the current application: i) wealth accumulation prior to retirement is valuable in retirement; ii) the value of accumulated wealth is negatively related to life expectancy (as the actuarially fair annuity value of wealth depends negatively on life expectancy); and iii) financing consumption out of accumulated wealth is a substitute for funding consumption from public pension benefits. However, by simplifying the consumption process in this way, we cannot study the effects of life expectancy or pension reforms on the post-retirement consumption process as in, e.g., De Nardi et al. (2009, 2010).

2.6 Optimal Labor Supply, Retirement and Consumption

2.6.1 Solution Method

Drawing on dynamic programming techniques, we use our model to describe an individual's optimal employment, retirement and consumption behavior over the life-cycle. In what follows, we use $\check{t}$ to denote the individual's age in the next quarter, i.e., $\check{t} \equiv t + 0.25$. In the interest of notational simplicity we omit the i subscript throughout the presentation of the dynamic programming problem. An individual's age t optimization problem can be expressed in terms of the state-specific value functions $V_t^{j,c}(p_t)$ for $j = f, u, r$, which define the maximized discounted expected value of the individual's future life-cycle utility conditional on being in state j with current consumption of c. Here, p_t denotes the time t values of the individual's state variables.[12] The state-specific value functions are defined recursively as follows

$$\begin{aligned} V_t^{f,c}(p_t) &= U_t(c,f) + \delta k_{\check{t},t} \mathrm{E}[V_{\check{t}}(p_{\check{t}}) | d_t = f, c_t = c, p_t], \qquad (10) \\ &= U_t(c,f) + \delta k_{\check{t},t} \left[\Gamma_{\check{t}} \left\{ \Lambda_{\check{t}} \mathrm{Emax}\{V_{\check{t}}^u(p_{\check{t}}), V_{\check{t}}^r(p_{\check{t}})\} + (1-\Lambda_{\check{t}}) \mathrm{E} V_{\check{t}}^u(p_{\check{t}}) \right\} + \right. \\ &\left. (1-\Gamma_{\check{t}}) \left\{ \Lambda_{\check{t}} \mathrm{Emax}\{V_{\check{t}}^f(p_{\check{t}}), V_{\check{t}}^u(p_{\check{t}}), V_{\check{t}}^r(p_{\check{t}})\} + (1-\Lambda_{\check{t}}) \mathrm{Emax}\{V_{\check{t}}^f(p_{\check{t}}), V_{\check{t}}^u(p_{\check{t}})\} \right\} \right], \qquad (11) \end{aligned}$$

$$\begin{aligned} V_t^{u,c}(p_t) &= U_t(c,u) + \delta k_{\check{t},t} \mathrm{E}[V_{\check{t}}(p_{\check{t}}) | d_t = u, c_t = c, p_t], \qquad (12) \\ &= U_t(c,u) + \delta k_{\check{t},t} \left[(1-\Theta) \left\{ \Lambda_{\check{t}} \mathrm{Emax}\{V_{\check{t}}^u(p_{\check{t}}), V_{\check{t}}^r(p_{\check{t}})\} + (1-\Lambda_{\check{t}}) \mathrm{E} V_{\check{t}}^u(p_{\check{t}}) \right\} + \right. \\ &\left. \Theta \{ \Lambda_{\check{t}} \mathrm{Emax}\{V_{\check{t}}^f(p_{\check{t}}), V_{\check{t}}^u(p_{\check{t}}), V_{\check{t}}^r(p_{\check{t}})\} + (1-\Lambda_{\check{t}}) \mathrm{Emax}\{V_{\check{t}}^f(p_{\check{t}}), V_{\check{t}}^u(p_{\check{t}})\} \} \right], \qquad (13) \end{aligned}$$

$$V_t^r(p_t) = U_t(c_t^r, r) + \delta k_{\check{t},t} \mathrm{E}[V_{\check{t}}^r(p_{\check{t}}) | d_t = r, c_t = c_t^r, p_t]. \qquad (14)$$

In (10)-(14), all expectations are conditional on information available to the individual at time t and on the individuals time t employment, retirement and consumption choice. Λ_t is the

[12]The state variables are: W; q; μ^{Θ}; μ^{Γ}; η; τ; υ; ε_j for $j = f, u, r$; α; z; x; and the current values of the parameters that define the tax, transfer and pension systems. See Sections 2.1-2.5 for further details.

individual's probability of being eligible for retirement at age t.[13] Meanwhile, $V_{\check{t}}^{f}(p_{\check{t}})$ and $V_{\check{t}}^{u}(p_{\check{t}})$ are defined as the age $\check{t}$ value functions associated with age $\check{t}$ employment and unemployment, respectively, after age $\check{t}$ consumption has been optimized. Specifically,

$$V_{\check{t}}^{j}(p_{\check{t}}) = \max_{c} V_{\check{t}}^{j,c}(p_{\check{t}}) \quad \text{for} \quad j = f, u. \tag{15}$$

At age t, a forward-looking optimizing individual in possession of a job offer but not eligible for retirement will choose employment and a current-period consumption level of c' if and only if $V_t^{f,c'}(p_t) > \max_{c,c \neq c'} V_t^{f,c}(p_t)$ and $V_t^{f,c'}(p_t) > \max_c V_t^{u,c}(p_t)$, and otherwise will choose unemployment and consumption $c = \max_c V_t^{u,c}(p_t)$. If such an individual instead is eligible for retirement then he or she will choose employment and a current-period consumption level of c' if, in addition to the previous two inequalities, it is also the case that $V_t^{f,c'}(p_t) > V_t^{r}(p_t)$. An individual who does not have a job offer and is not eligible early retirement will be unemployed with a current-period consumption level of $c = \max_c V_t^{u,c}(p_t)$. Alternatively, if this individual is eligible for retirement then he or she will choose unemployment with a current-period consumption level of c' if and only if $V_t^{u,c'}(p_t) > \max_{c,c \neq c'} V_t^{u,c}(p_t)$ and $V_t^{u,c'}(p_t) > V_t^{r}(p_t)$.

2.6.2 Discussion

Several mechanisms link an individual's current employment, retirement and consumption decisions with expected future payoffs. We discuss here intertemporal dependencies that are related directly to retirement.

Current employment adds to an individual's stock of pension points and, therefore, holding fixed the age of retirement, increases pension income in retirement. Current unemployment has a similar albeit smaller effect, provided that the unemployed individual is receiving Unemployment Insurance. Furthermore, working in the current period adds to the individual's experience which, in the presence of positive wage returns to experience, leads to higher expected future wage offers and, *ceteris paribus*, to higher public pension benefits in retirement. Finally, accumulation of wealth prior to retirement, *ceteris paribus*, allows an individual to increase income in retirement.

Life expectancy interacts with the above-described intertemporal dependencies. An increase in life expectancy increases the expected duration over which an individual will receive public pension benefits. An increase in life expectancy therefore, *ceteris paribus*, raises the expected return to accumulation of pension points, and creates an incentive to postpone retirement. Further, an increase in life expectancy increases the time over which an individual may enjoy the returns from accumulated wealth. Therefore, ignoring interactions with other behavioral adjustments, the incentive to save is increasing in life expectancy.

The total effect of an increase in life expectancy on behavior over the life-cycle is however, *a priori*, impossible to determine. An individual may respond to an increase in life expectancy

[13] Reintroducing the i subscript and following the discussion above in Section 2.4, an individual may be eligible for retirement at age t either on the grounds of disability, an event which occurs with probability $\Upsilon_{i,t}$ as defined above in equation (7), or due to having satisfied the relevant age, gender and working history based criteria. Therefore, the probability of an age t individual being eligible for retirement, $\Lambda_{i,t}$, takes the following form:

$$\Lambda_{i,t} = \begin{cases} 1 & \text{if age, gender and working history based criteria for retirement eligibility are satisfied;} \\ \Upsilon_{i,t} & \text{otherwise.} \end{cases}$$

Finally, all individuals may retire at the full pensionable age (FPA) and therefore $\Lambda_{i,t} = 1$ for all $t \geq \text{FPA}$.

by increasing both employment and wealth accumulation. Alternatively, the individual may find it optimal to increase employment and reduce wealth accumulation, or vice versa. Further, an increase in life expectancy may lead to higher saving or increased employment early in the life-cycle followed by earlier retirement. Optimizing behavior does, however, rule out an increase in life expectancy causing weakly lower saving and weakly higher unemployment early in the life-cycle followed by strictly earlier retirement.

3 Data Sources and Sample Selection

The estimation uses data from the German Socio-Economic Panel and the Human Mortality Database.

3.1 German Socio-Economic Panel (SOEP)

The German Socio-Economic Panel (SOEP) is an annual, representative panel survey of over 11000 German households. As described by Wagner et al. (2007), the SOEP contains information about socio-economic variables, including income and working behavior, at the individual and household levels. We use the SOEP surveys from the years 1992 - 2008, which contain retrospective information covering the fiscal years 1991 - 2007.

Our sample selection criteria are designed to ensure a clean empirical implementation of the above-described theoretical model. We use a sample of individuals aged 40 years and above who reside in single-adult households and who do not have dependent children. In more detail, we take the SOEP data for 1991 - 2007 and for each individual we identify the first quarter in which the individual is aged 40 or above, single and without dependent children. We then follow the individual until he or she drops out of the SOEP data, starts cohabiting, or reports having a dependent child.[14] We exclude those whose primary earnings are from self-employment and those in full-time education because the labor supply behavior of members of these groups differs substantially from that of the rest of the population under study. We exclude civil servants because they face a different retirement system. The estimation sample is further restricted to individuals aged 40-64.75 years inclusive (recall for estimation we impose that working at or beyond the full pensionable age of 65 years is impossible). The estimation sample is an unbalanced panel with 40490 person-quarter observations, consisting of 2389 distinct individuals of whom 55% are women. The median number of observations per individual is 11 quarters but a substantial fraction of individuals are observed for much longer: around 25% of the individuals are observed for least 24 quarters and around 15% of individuals are observed for at least for 32 quarters.[15]

The SOEP data set contains self-reported information about individuals' employment and retirement behavior in each month. We group the monthly information and form quarterly observations with an individual's labor market status in the first month of the quarter determining

[14] Through the initial conditions, our econometric analysis recognizes that individuals may have been married or had dependent children prior to entering the sample. See Appendix C.1 for further details. The information on previous children, marital status and labor supply needed to implement our treatment of the initial conditions is provided by the retrospective questions in the SOEP survey. We assume the sampled individuals do not start cohabiting or acquire dependent children subsequent to entering the sample.

[15] See Kroh and Spieß (2008) for a discussion of attrition in the SOEP.

the quarterly outcome.[16] We construct our sample such that each period an individual is full-time employed, unemployed or retired. All individuals who report that they are currently retired, or who have reported being retired at some point in the past, are classified as retired.[17] As in, e.g., Low et al. (2010), in our sample the group of unemployed individuals comprises all non-working, non-retired individuals. The definition of "unemployment" used when constructing the sample is therefore consistent with the above theoretical framework, in which involuntary job separations, voluntary quits and refusals of job offers are permitted. In some related studies, the group of non-working non-retired individuals is divided explicitly into participants and non-participants (e.g., Garibaldi and Wasmer, 2005, and Frijters and van der Klaauw, 2006). We instead include heterogeneity in income, opportunities and preferences among unemployed individuals: job opportunities differ by observable and unobservable characteristics; preferences include permanent unobserved taste shifters; and Unemployment Insurance is available only to those individuals with qualifying employment histories. In this way, on average, any estimated behavioral responses will account for the composition of the unemployment pool.

Table 1 summarizes the employment and retirement behavior of individuals in the estimation sample. Conditional on age and gender, the employment rate is 10-20 percentage points higher in west Germany than in the east, and older east Germans have a higher propensity to retire than west Germans of the same age. These differences are likely related to the relatively poor economic conditions in east Germany. We also see that women are somewhat less likely than men to be employed, and are more likely to be retired. In the empirical implementation we account for gender differences in behavior by allowing wages, health status and access to retirement to vary with gender (see Section 4). In this way, we capture gender difference in pension point accumulation.

Table 1: Employment and retirement by age, gender and region of residence.

	Age 40-50 years		Age 50.25-64.75 years	
	Employment	Retirement	Employment	Retirement
East German men	67.2	7.4	41.3	34.6
West German men	86.0	4.9	51.4	33.3
East German women	65.5	13.2	23.2	59.1
West German women	82.6	6.6	37.2	37.1

Notes: Retirement and employment figures are percentages. All quantities were computed using the estimation sample and are averages over the observation period.

The SOEP data set includes individuals' gross earnings in the month prior to the interview date. Using the corresponding working hours, including hours of paid overtime work, we construct a gross hourly wage measure. We follow Fuchs-Schuendeln and Schuendeln (2005) and construct a measure of individual-level wealth based on the yearly financial information available in the SOEP. Specifically, an individual's wealth is defined as the sum of net property equity and non-property wealth, where the latter is computed from capital income assuming that the real rate of return, r, is 3% per annum. Wealth and wages are converted to year 2000 prices using the Retail Price Index. The average observed gross hourly wage is 15.65 Euros and average individual wealth is 40037 Euros.

[16] Given our sample selection criteria, fewer than 5% of the male (female) population under study work fewer than 30 (25) hours per week. It is therefore reasonable to treat all employment as full-time work.

[17] Our definition of retirement corresponds closely to observed behavior: less than 5% of retired individuals are simultaneously in employment, and only 1% of retired individuals report that they work full-time.

Individual-level experience in each quarter is computed by taking a measure of years of experience at the time of sample entry and then updating this variable sequentially through the sample period, with 0.25 being added to experience for each quarter of full-time work. Retrospective information in the SOEP data allows us to construct the measure of experience at the time of sample entry. Our measure of health is an indicator variable that takes the value one if the individual self-reports the presence of health problems that limit daily activities, and is zero otherwise. Henceforth, this indicator variable is termed “health problems”. It is well-known that self-reported health is sensitive to social and attitudinal factors (Baker et al., 2004); over time self-reported health may not track life expectancy (Verbrugge, 1984). We therefore refrain from including cohort effects in health in the estimated model, and instead opt to remove any cohort effects from self-reported health before estimation of the structural parameters (see footnote 33 for further details).

3.2 Human Mortality Database (HMD)

We obtain information about longevity in Germany from the relevant life tables in the Human Mortality Database (HMD).[18] The life tables include survival probabilities and life expectancies that vary by age, birth cohort, region of residence (east or west Germany) and gender and are available for the years 1991 - 2007. Based on the information in the HMD, we assign a demographic group-specific and cohort-specific survival probability and life expectancy to each observation in our SOEP sample, thus forming a combined SOEP-HMD sample.[19] The combined SOEP-HMD sample restricted to individual’s ages 40-64.75 inclusive is henceforth referred to as the “SOEP-HMD estimation sample”.

Figure 1 shows the evolution over time of life expectancy at age 65 years for east and west German men and women. As expected, we observe higher life expectancies for women and, irrespective of gender or region, an upward trend in life expectancy over time. As documented in the demographic literature, e.g., Gjonça et al. (2000), life expectancy in east Germany in 1991, immediately after German reunification, was considerably lower than in west Germany: in 1991 a 65 year old east German man expected to live 1.4 years less than his west German counterpart, and the corresponding difference for women was 1.93 years. More important for our purpose are the different trends by gender and region: between 1991 and 2007 there was a strong east-west convergence in life expectancy for women and moderate east-west convergence for men. According to Gjonça et al. (2000), Nolte et al. (2002) and Kibele and Scholz (2008), the leading reason for this convergence was improvements in health-care in east Germany.

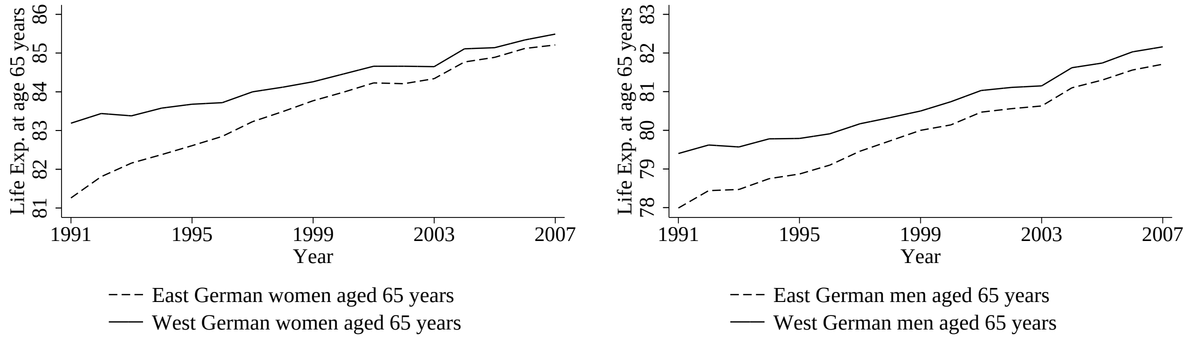
In the life-cycle model presented in Section 2 the timing of retirement varies with life expectancy. To the extent that higher life expectancy leads individuals to work longer to increase entitlement to the public pension we expect, all else equal, a negative relationship between life expectancy and prevalence of retirement before age 65 years (although as discussed above in Section 2.6.2 other behavioral responses are also possible). We draw on the different trends in life expectancy between gender-region groups and quantify the relationship between life expectancy

[18]Human Mortality Database was provided by the University of California, Berkeley (USA) and Max Planck Institute for Demographic Research (Germany). The database is available at www.mortality.org.

[19]The HMD does not contain information about marital status. In general, the life expectancy of single individuals is lower than that of married individuals. This may bias our estimate of the subjective time discount factor downward.

Figure 1: Life expectancy at age 65 years: evolution over time in east and west Germany.

(a) Women. (b) Men.



Source: Authors' calculations based on the Human Mortality Database for Germany.

and retirement in our SOEP-HMD estimation sample.[20] Specifically, we use panel regressions with individual-level random effects to estimate the effect of life expectancy at age 65 years on the probability of an individual being retired in the current quarter. The regressions include dummies for male and west German, a male-west German interaction, and dummies for age, birth cohort and year. Dependent on the specification, we include additional demographic controls or demographic group fixed effects. The notes accompanying Table 2 provide further details.

Table 2: Life expectancy and the probability of being retired.

	1	2	3	4	5
Life expectancy at age 65 years	-0.104^{***} (0.022)	-0.092^{***} (0.023)	-0.084^{***} (0.024)	-0.104^{***} (0.031)	-0.149^{***} (0.040)
Male	-0.428^{***} (0.070)	-0.445^{***} (0.071)	-	-	-
West German	-0.153^{***} (0.020)	-0.169^{***} (0.020)	-	-	-
Male × West German	0.163^{***} (0.029)	0.177^{***} (0.029)	-	-	-
Additional demographic controls	No	Yes	Not Applicable	Not Applicable	Not Applicable
Demographic group fixed effects	No	No	Yes	Yes	Yes
Age restriction (years)	40 - 64.75	40 - 64.75	40 - 64.75	45 - 64.75	50 - 64.75
Person-quarter observations	40490	40490	40490	34175	27483

Notes: ***, ** and * denote significance at the 1%, 5% and 10% levels. The dependent variable is an indicator of the individual being retired in the current quarter. Results were obtained panel regressions with individual-level random effects. All specifications include dummies for age (rounded down), cohort (year of birth) and year. Additional demographic controls are years of education and indicators for native German, pre-sample marriage and pre-sample dependent children. Demographic group fixed effects are dummies for the 204 groups defined by all possible combinations of gender, west German and the additional demographic controls. Hetroskedasticity-robust standard errors, clustered at the individual level, are shown in parentheses.

[20]In different settings, Alesina and Fuchs-Schuendeln (2007), Fuchs-Schuendeln (2008) and Fuchs-Schuendeln and Schuendeln (2005) also exploit variation generated by German reunification.

Table 2 summarizes the estimated relationship between life expectancy and the probability of retirement. The results for Specification 3, which includes demographic group fixed effects, show that a one year increase in age 65 life expectancy is associated with a 8.4 percentage point decrease in the probability of an individual being retired (2-sided p-value of less than 0.01). Similar results are obtained from the more parsimonious Specifications 1 and 2, which have fewer controls for demographic variables. In Specifications 4 and 5 we restrict the estimation to older individuals and find a stronger relationship between life expectancy and the probability of retirement. The latter result is consistent with life expectancy becoming an increasingly important determinant of behavior as individuals approach the full pensionable age of 65 years.

In light of the extensive heterogeneity in life expectancy, the empirical implementation of our structural life-cycle model permits variation in life expectancy according to birth cohort, gender, region of residence and age. This maximizes the model's accuracy. Further, in Section 4.2 we draw on this feature of the model by conducting an in-sample goodness of fit test of the structural model that leverages the demographic group-specific trends in life expectancy. Specifically, we compare the relationship between life expectancy and the probability of retirement as given by Specification 3 in Table 2 with the corresponding quantity implied by the estimated structural model.

4 Estimation Strategy and Results

4.1 Overview of Estimation Strategy and Identification

The structural parameters are estimated using Indirect Inference (see Gourieroux et al., 1993). The backbone of this estimation approach is an auxiliary model, the parameters of which can be estimated using either the SOEP-HMD estimation sample or samples simulated using the data generation process described by the structural model. Estimation proceeds as follows. Let θ denote the column vector of structural parameters. For a given value of θ, K simulated samples are generated. Let γ denote the p-by-1-dimensional vector of auxiliary model parameters estimated using the SOEP-HMD estimation sample. Further, let $\gamma_k^s(\theta)$ denote the same vector of parameters estimated using the k^{th} simulated sample. The Indirect Inference estimator $\widehat{\theta}_N^K$ is defined by

$$\widehat{\theta}_N^K \in \underset{\theta}{\operatorname{argmin}} \left(\gamma - \frac{1}{K} \sum_{k=1}^{K} \gamma_k^s(\theta) \right)' W_N \left(\gamma - \frac{1}{K} \sum_{k=1}^{K} \gamma_k^s(\theta) \right), \tag{16}$$

where W_N is a p-by-p-dimensional positive definite weighting matrix.

We seek to match 265 auxiliary model parameters via the choice of 82 structural parameters. Our auxiliary model consists of sub-models of wealth, wages and employment dynamics (Adda et al., 2011, adopt a similar estimation approach to estimation of the parameters of a structural life-cycle model). Appendix C provides further details on the estimation strategy and identification.

4.2 Structural Parameter Estimates

Table 3 reports the structural parameter estimates. (Table 8 in Appendix D presents our estimates of the parameters appearing in the initial conditions.) Looking first at the wage equation, we find offered wages increase significantly with experience. This finding underlines the importance of experience-based human capital accumulation in the determination of wage offers, and more generally for labor supply behavior over the life-cycle. Offered wages are higher in west Germany than in the east, and native Germans and men receive significantly higher wage offers than immigrants and women respectively. The estimated rate of return to one year of education is 8.34%. Unobservables are found to play an important role in wage determination. Of the permitted unobservables, the permanent individual effect, α_i, has the highest standard deviation and therefore has the largest impact on wage offers. This finding implies unobserved differences in wages are driven primarily by differences in permanent unobserved individual characteristics. However, we also find a significant unobserved match-specific effect; quantitatively, we find each quarter an individual has a 14.8% chance of receiving a new match-specific draw. This corresponds to an individual receiving a new match-specific draw on average every 6.8 quarters.[21]

The job offer and involuntary separation probabilities display clear age patterns: older individuals are less likely to receive job offers and are more likely to be subject to involuntary separations than their younger counterparts. To interpret the age effects in the job offer and involuntary separation probabilities, note that our model of net income includes the relevant age-related eligibility criteria for Unemployment Insurance and public pension benefits (we also model the dependence of net income on Social Assistance, Social Security Contributions and income taxation, but these institutions do not feature age-based eligibility rules). The age terms in employment opportunities therefore reflect age effects beyond those driven by the age-based eligibility rules for social transfers and pension benefits. The same argument applies to the age terms in the wage equation. As expected, those in poor health and those living in east Germany are relatively more likely to experience an involuntary separation and are relatively less likely to receive a job offer. Unobserved individual characteristics have significant effects on the job offer and involuntary separation probabilities. The unobservables affecting job offers and involuntary separations are significantly negatively correlated. We find that the probability of being eligible for early retirement on the grounds of disability is related positively and significantly (at the 5.4% level) to the presence of health problems.

[21] This results suggests match-specific wage shocks occur at a higher frequency than job changes. Therefore, we conclude that individuals can experience persistent wage shocks without changing jobs.

Table 3: Structural parameter estimates.

	Coefficient	Standard Error
Wage Equation		
Intercept	1.564	0.076
Male	0.069	0.056
West German	0.335	0.046
Male $\times$ West German	0.154	0.065
Education (years)/10	0.834	0.053
Experience (years)/50	0.330	0.090
Native German	0.079	0.035
$\min(\text{Age} - 54, 5)\text{I}(\text{Age} \geq 54)/10$	-0.040	0.097
$(\text{Age} - 59)\text{I}(\text{Age} \geq 59)/10$	-0.181	0.138
Health problems	-0.038	0.033
Probability of receiving a new match-specific effect (Π)	0.148	0.048
Standard deviation of match-specific effect (σ_τ)	0.085	0.008
Standard deviation of permanent individual effect (σ_α)	0.222	0.034
Standard deviation of transitory shock (σ_υ)	0.023	0.006
Job Offer Probability (Θ)		
Intercept	-2.374	-0.144
$\min(\text{Age} - 40, 14)\text{I}(\text{Age} \geq 40)/14$	-0.278	0.166
$\min(\text{Age} - 54, 5)\text{I}(\text{Age} \geq 54)/5$	-1.311	0.271
$(\text{Age} - 59)\text{I}(\text{Age} \geq 59)/5$	-0.398	0.731
West German	0.814	0.133
Health problems	-0.197	0.206
Standard deviation of individual effect in job offer probability (Σ^μ_{11})	1.029	0.064
Involuntary Separation Probability (Γ)		
Intercept	-4.759	0.339
$\min(\text{Age} - 40, 14)\text{I}(\text{Age} \geq 40)/14$	2.984	0.388
$\min(\text{Age} - 54, 5)\text{I}(\text{Age} \geq 54)/5$	0.337	0.204
$(\text{Age} - 59)\text{I}(\text{Age} \geq 59)/5$	2.984	0.459
West German	-1.940	0.288
Health problems	0.964	0.218
Standard deviation of individual effect in separations (Σ^μ_{22})	0.798	0.125
Covariance between individual effects in arrivals and separations (Σ^μ_{12})	-0.657	0.124
Preferences		
Coefficient on consumption (β)	5.839	1.046
CRRA (ρ)	2.565	0.138
Mean of complementary parameter (μ_η)	0.221	0.044
Standard deviation of complementarity parameter (σ_η)	0.112	0.059
Annual subjective time discount factor (δ)	0.989	0.008
Probability of Retirement Eligibility on the Grounds of Disability (Υ)		
Intercept	-0.745	0.457
Health problems	0.797	0.414
Male	0.384	0.374

Notes: The mean and standard deviation of the complementarity parameter (η_i) after allowing for truncation are 0.231 (with a standard error of 0.023) and 0.106 (with a standard error of 0.028) respectively.

The coefficient on consumption, β, is significantly greater than zero which implies that individuals' behavior is influenced by the financial incentives associated with employment, retirement and wealth accumulation. We find that the individual-specific parameter that describes the complementarily between consumption and leisure, η_i, varies significantly across individuals. After allowing for truncation from above at 0.999 and from below at 0, the mean value of η_i is 0.231. This implies that on average 23.1% of consumption is required to compensate an employed individual for the disutility of working. Our estimate of the annualized subjective time discount factor is 0.989, a figure in line with previous findings (e.g., De Nardi et al., 2010). Finally, our estimate of the CRRA parameter, ρ, is 2.565 and we thus find that individuals are risk averse. Both the subjective time discount factor and the CRRA parameter are precisely estimated, which lays testament to the quality and relevance of the available consumption information.[22]

4.3 Goodness of Fit

The estimated model is able to fit the observed relationship between life expectancy and retirement, explored in Section 3.2. In more detail, we focus on Specification 3 in Table 2, which describes the relationship between life expectancy and the probability of an individual being retired, controlling for age, time, cohort and demographic group fixed effects. We re-estimate Specification 3 using five samples simulated from the estimated structural model. The average coefficient on life expectancy across these regressions is -0.053, a figure that is 1.3 standard errors away from the corresponding observed quantity of -0.084. When formulating the structural model we assumed individuals are fully informed about life expectancy, and that they use information about life expectancy when forming expectations about the future consequences of current actions. The ability of the model to fit the observed relationship between life expectancy and retirement supports these assumptions. We thus conclude that our model provides a sound basis for counterfactual policy simulations that investigate the effect of life expectancy on life-cycle behavior.

Our flexible specification of the wage process allows the model to replicate the distributions of wages and changes in wages (see Table 4). Recall, the wage process includes permanent, autocorrelated and transitory unobservables (see Section 2.3). We found less flexible specifications, without permanent and/or autocorrelated unobservables, performed significantly worse in terms of their ability of fit percentiles of the distributions of differences between wages one, two and three years apart. Further, the model fits the age profiles of labor supply, retirement, wealth and transitions between employment and unemployment (see Figure 2). Notably, the model is able to fit the observed peak in unemployment that occurs at around age 60 years. To understand the contribution of Unemployment Insurance and the disability pension system to this aspect of model fit, we re-simulated life-cycle behavior: i) without Unemployment Insurance; and ii) without the disability pension system. Our results show that elimination of Unemployment Insurance reduces the unemployment rate by an average of 2.6 percentage points between the ages of 40 and 65 years and by 5.6 percentage points at age 60 years. The disability pension system, meanwhile, reduces the number of people who use unemployment as an entry route into retirement - removal of the disability pension system increases the unemployment rate by an average of 2.1 percentage points between the ages of 40 and 65 years and by 5.9 percentage points at age 60 years.

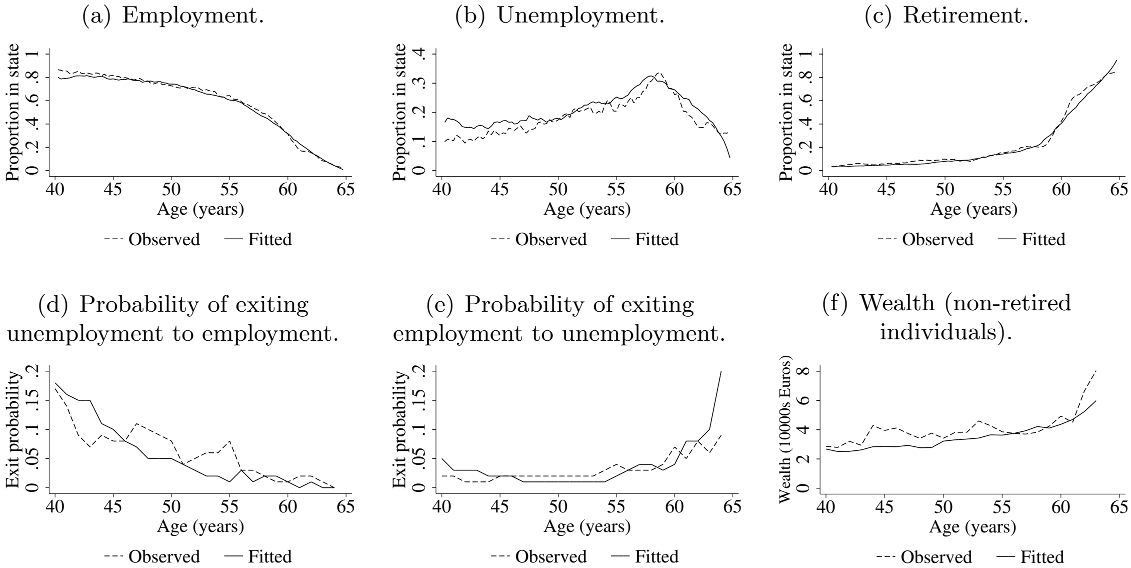
[22]The CRRA and the subjective time discount factor are the parameters most likely to depend strongly on the sustainability factor (see Section 2.4.3). We checked the robustness of our estimates of these key preference parameters to our treatment of the sustainability factor by re-estimating the structural parameters excluding observations from 2005-2007 inclusive, the period in which the sustainability factor was in operation. Our estimates of the CRRA and the subjective time discount factor are relatively unaffected, despite dropping almost 20% of the observations used in the primary analysis. Based on the 1991-2004 sample, our estimate of the CRRA is 2.739 and our estimate of the subjective time discount factor is 0.995.

Table 4: Fit of log wages and changes in log wages.

	$P_{20}(w^*)$	$P_{40}(w^*)$	$P_{60}(w^*)$	$P_{80}(w^*)$	$P_{20}(\Delta^1 w^*)$	$P_{40}(\Delta^1 w^*)$	$P_{60}(\Delta^1 w^*)$	$P_{80}(\Delta^1 w^*)$
Fitted	-0.011	0.201	0.388	0.607	-0.076	-0.016	0.022	0.082
Observed	-0.034	0.194	0.394	0.650	-0.080	-0.016	0.020	0.098
SE	0.020	0.016	0.017	0.026	0.005	0.001	0.002	0.006
t-value	1.162	0.411	-0.356	-1.627	0.845	0.034	1.069	-2.446
	$P_{20}(\Delta^2 w^*)$	$P_{40}(\Delta^2 w^*)$	$P_{60}(\Delta^2 w^*)$	$P_{80}(\Delta^2 w^*)$	$P_{20}(\Delta^3 w^*)$	$P_{40}(\Delta^3 w^*)$	$P_{60}(\Delta^3 w^*)$	$P_{80}(\Delta^3 w^*)$
Fitted	-0.096	-0.018	0.033	0.107	-0.101	-0.019	0.041	0.122
Observed	-0.087	-0.017	0.034	0.121	-0.084	-0.008	0.053	0.134
SE	0.006	0.003	0.003	0.009	0.008	0.005	0.005	0.009
t-value	-1.399	-0.212	-0.531	-1.497	-2.174	-1.960	-2.217	-1.361

Notes: $P_j(w^*)$ refers to the j^{th} percentile of log wages and $P_j(\Delta^r w^*)$ denotes the j^{th} percentile of the r^{th} annual difference in log wages. "Observed" refers to a value observed in the sample while "Fitted" refers to the value of the applicable quantity averaged over 5 samples simulated using the estimated structural model. "SE" is the standard error of the observed quantity (obtained via bootstrapping with clustering at the individual level) and "t-value" is the t-value for the test of equality of the observed and fitted quantities.

Figure 2: Fit of life-cycle behavior.



Notes: "Observed" refers to a value observed in the SOEP-HMD estimation sample while "Fitted" refers to the value of the applicable quantity averaged over 5 samples simulated using the estimated structural model.

5 Policy Analysis

5.1 Longevity, Life-cycle Behavior and Government Revenue

The behavioral and fiscal implications of increasing life expectancy must be understood prior to determining how public pension systems may be reformed to ensure financial stability in the face of improving longevity. To this end, we compare the optimal life-cycle behavior and associated tax, transfer and pension payments of two groups of individuals who differ only with respect to life expectancy and, therefore, health. Each individual in the first group is assigned the appropriate gender-specific and region-specific life expectancy of the 1942 birth cohort, the cohort who reached age 65 years in 2007. Meanwhile, each individual in the second group is assigned the appropriate predicted individual-specific life expectancy of the 1982 birth cohort, who will reach age 65 years

40 years after individuals in the first group, i.e., in 2047. According to the HMD for Germany, life expectancy at age 65 is anticipated to be on average 6.4 years higher for the 1982 birth cohort than for the 1942 birth cohort. In this analysis, we allow health to improve in line with life expectancy, and in doing so we capture the effect of improved health on wages, job offer and involuntary separation probabilities, and access to the disability pension. Specifically, we assume that the probability of being in bad health at age x when age 65 life expectancy is y is the same as the probability of bad health at age $x + z$ when age 65 life expectancy is $y + z$.[23] For both groups, we fix the distribution of all characteristics other than life expectancy and health at that observed in our sample and we impose the year 2007 tax, transfer and pension systems.

As explained above in Section 2.4.2, when estimating the model we assumed that employment at or beyond the full pensionable age of 65 years is impossible, and we justified this assumption based on the low empirical frequency of employment among individuals aged 65 years and above. However, for the purpose of the counterfactual policy simulations presented here and below in Section 5.2 we relax this restriction and allow individuals to work until age 80 years, irrespective of the policy parameters and irrespective of life expectancy.[24] The design of our counterfactual policy simulations therefore recognizes that, e.g., an increase in life expectancy or a cut in pension generosity may cause individuals to work beyond the full pensionable age. In the counterfactual policy simulations, an individual choosing to work at or beyond the full pensionable age faces the correct post-full pensionable age pension rules (see Section 2.4.2), and is subject to the same job offer and involuntary separation probabilities as applicable to him or her one quarter prior to the full pensionable age. The probability of health problems after age 65 years is obtained by extrapolating over age using the estimated equation of motion for health problems (see Appendix C.2). Once an individual reaches the full pensionable age he or she ceases to be eligible for Unemployment Insurance and Social Assistance benefits. In our counterfactual simulations, therefore, we do not allow individuals aged at or above the full pensionable age to be unemployed.[25]

Figures 3(a) - 3(c) show how the rates of employment, unemployment and retirement are affected by the 6.4 year increase in age 65 years life expectancy anticipated to occur between the 1942 and 1982 birth cohorts. This increase in life expectancy reduces the retirement rate by an average of approximately 1.2 percentage points for those aged 40-65 years and by around 5.5 percentage points for individuals aged 64 years.[26] Looking at behavior close to the full pensionable age of 65 years we see that the postponement of retirement is balanced by increases in employment and unemployment. Two factors lead the postponement of retirement to be associated with higher unemployment. First, those wanting to retire later may have difficulty finding or keeping a job as older individuals are subject to a relatively low job offer rate and

[23]Shifting health with life expectancy in this way means that the average prevalence of health problems among individuals aged 40 years and above is roughly constant as life expectancy increases. This is consistent with the predictions of Jacobzone et al. (2000) for Germany.

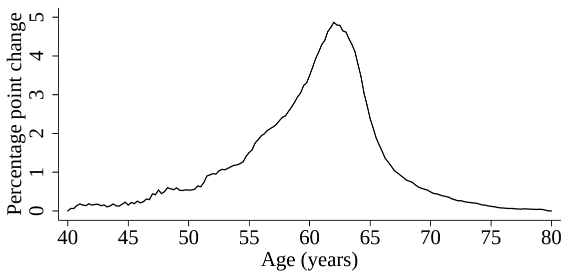
[24]The extended model replicates the observed employment rate of around 1% for individuals aged 65-70 years. Specifically, the employment rate for individuals aged 65-70 years is 1.1% in data simulated from the extended model, and 0.5% in the SOEP data.

[25]Allowing the 1942 cohort to work past age 65 increases its mean retirement age by 0.09 of a year.

[26]The employment response among those aged 40-50 years is quantitatively small. This is to be expected, given the employment rate can only change due to individuals accepting job offers rather than staying in unemployment, or remaining in employment instead of quitting. If additionally individuals could adjust behavior along the intensive marginal then the change in the employment rate for individuals in their 40s might be larger. Similarly, in the case of couple households we would expect an additional response from secondary earners.

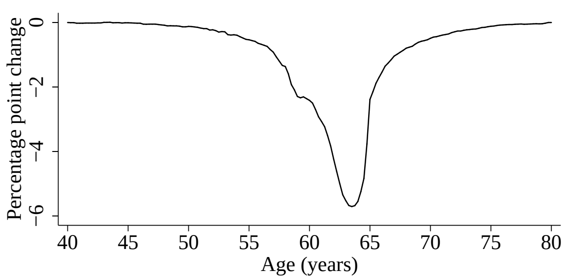
Figure 3: Life expectancy and behavior over the life-cycle.

(a) Employment.



(b) Unemployment.

(c) Retirement.



(d) Net Government revenue per person per month.

Notes: All sub-figures show the effect of a 6.4 year increase in age 65 life expectancy.

a relatively high involuntary separation rate (see Section 4.2). Second, the entitlement period for Unemployment Insurance is increasing in age and this encourages older individuals to use unemployment as a stepping-stone into retirement. The effect on employment of an increase in life expectancy is small for individuals aged 65 years and above; this finding again reflects that older individuals face relatively unfavorable job offer and involuntary separation probabilities.

We next consider the effect of an increase in life expectancy on net Government revenue, NGR, which takes the following form

$$\text{NGR} = \text{Income Tax} + 2 \times \text{SSC} - \text{UIB} - \text{SAB} - \text{Public Pension Benefits}, \tag{17}$$

where Income Tax consists of taxes paid on labor income, pension income and interest income from wealth holdings, SSC denotes individual Social Security Contributions (this figure is multiplied by two because firms must match individuals' contributions), while UIB and SAB correspond, respectively, to Unemployment Insurance and Social Assistance benefits. Figure 3(d) shows that an increase in life expectancy causes net revenue received from individuals aged below around 67 years to increase, a change that reflects the increase in the employment rate. However, by working more individuals increase their pension entitlement upon retirement, and this leads to an increase in the average monthly net transfer made to older individuals.

Finally, we aggregate the fiscal effects of an increase in life expectancy over the life-cycle: we construct a quantity called "average per-person net Government revenue", which is calculated by summing the net Government revenue (NGR) for each individual in each period between

Table 5: Effect of an improvement in life expectancy on net Government revenue, years of employment, timing of retirement, and consumption at age 65 years.

Birth Cohort	Life Exp. at 65	Net Government Revenue Per Person: All	Emp.	Unemp.	Retired	Yr Emp. Age>40	Ret. Age	Pension Points	Inc. from Wealth	Cons. at Age 65
1942	83.3	66002	294627	-26518	-202107	18.27	62.32	39.88	160.85	1083.63
1982	89.7	-93	310059	-26290	-283862	18.78	62.69	40.50	127.50	1075.77
Change	6.4	-66095	15432	228	-81755	0.51	0.37	0.62	-33.35	-7.86

Notes: "Yr Emp. Age > 40" is the average years of employment post age 40 years and "Ret. Age" is the average age of retirement. "Pension Points" is the average number of weighted pension points accumulated prior to the date of retirement. "Inc. from Wealth" is the average per-person actuarially-fair monthly annuity income wealth at the date of retirement. "Cons. at Age 65" is the average monthly consumption at age 65 years. Government revenue, income and consumption figures are in Euros.

age 40 years and death, and then averaging over individuals. Table 5 shows that the 6.4 year increase in age 65 life expectancy anticipated to occur over the 40 years that separate the 1942 and 1982 birth cohorts causes average per-person net Government revenue to decrease by 66095 Euros.[27] Decomposing, the increase in life expectancy under consideration has a minor positive effect on the average revenue received from unemployed individuals, and causes net Government revenue received from employed individuals to increase by an average of 5.1% or 15432 Euros per person. However, the average net transfer made to retired individuals increase by 81755 Euros per person. Table 5 further shows the increase of employment and the postponement of retirement lead average weighted pension points accumulated by the date of retirement to increase by 0.62, or 1.55%. This additional accumulation of entitlement to the public pension works to offset the fall in average annuity income from wealth in retirement such that average consumption at age 65 years falls by only 7.86 Euros.

5.2 Transfer and Public Pension Reforms

Motivated by the substantial deterioration in the Government's budgetary position created by an increase in life expectancy, we explore the consequences of a range of pension and transfer reforms. First, we consider three focused reforms to the transfer and pension systems. These reforms are not designed to offset completely the fiscal cost of an increase in life expectancy, i.e., they are not revenue neutral in the face of an increase in life expectancy. Instead, these reforms are presented to place the fiscal cost of increasing life expectancy in the context of the revenue flows associated with specific changes in the transfer and pension systems. Second, we identify combinations of increases in the pension age thresholds and cuts in pension generosity that offset exactly the average deficit of 66095 Euros per person generated by the 6.4 year increase in age 65 life expectancy anticipated to occur over the 40 years that separate the 1942 and 1982 birth cohorts. Third, we provide some insights on the design of the optimal public pension system. Throughout this analysis, we continue to fix the distribution of all characteristics other than life expectancy, and therefore health, at that observed in our sample. Unless indicated otherwise, we continue to use the 2007 tax, transfer and pension systems.

For each reform, we compute the effects on employment, retirement age and asset holdings.

[27] Recall that in this analysis we allow health to improve with life expectancy. If instead health is held fixed as life expectancy increases, the considered 6.4 year increase in age 65 life expectancy would reduce average net Government revenue by around 75000 Euros per person and would increase average years of employment after age 40 years by approximately 0.1 of a year. An increase in life expectancy, therefore, has a larger effect on employment and lower fiscal consequences when it is accompanied by an improvement in health.

We also assess the welfare implications of each reform. Our measure of welfare is the fraction, ψ_i, by which baseline consumption must be adjusted to make the individual's life-time utility in the baseline environment equal to that in the post-reform environment. We interpret ψ_i as the value that the individual attaches to the reform. To obtain an expression for ψ_i we consider two environments, indexed by m: $m = 0$ is the baseline, and $m = 1$ is an alternative regime in which tax, transfer and/or pension rules have been amended relative to the baseline. Similar to Low et al. (2010), we start from the following expression for expected lifetime utility in environment m

$$\overline{EU}^m = \mathrm{E}_{40} \sum_{t=40}^{\overline{T}} k_{i,t,40} U_{i,t}(c_{i,t}^m, d_{i,t}^m) \quad \text{for} \quad m = 0, 1. \tag{18}$$

In the above, $c_{i,t}^m$ denotes the individual's consumption in environment m, and $d_{i,t}^m$ denotes the individual's employment and retirement outcome in environment m. The ψ_i that solves (19) gives the value that individual i places on the reform.

$$E_{40} \sum_{t=40}^{\overline{T}} k_{i,t,40} U_{i,t}((1 + \psi_i) c_{i,t}^0, d_{i,t}^0) = \overline{EU}^1. \tag{19}$$

Substituting the specification of the flow utility function given by (1) and (2) into (19) and rearranging yields

$$\psi_i = \left(\frac{\overline{EU}^1 - \overline{\varepsilon}^0}{\overline{EU}^0 - \overline{\varepsilon}^0} \right)^{\frac{1}{1-\rho}} - 1 \quad \text{where} \quad \overline{\varepsilon}^0 = E_{40} \sum_{t=40}^{\overline{T}} \sum_{j=f,u,r} k_{i,t,40} \varepsilon_{i,j,t}(d_{i,t}^0 = j). \tag{20}$$

Our primary measure of welfare is the average value of the reform, $\overline{\psi} = \sum_{i=1}^{N} \psi_i / N$.

5.2.1 Non-Revenue Neutral Reforms

The middle panel of Table 6 summarizes revenue flows and behavioral outcomes following: removal of the provision for Unemployment Insurance-eligible unemployed individuals to accumulate pension points; complete elimination of the Unemployment Insurance system; and elimination of the right to early retirement on the grounds of disability. Throughout this analysis, all individuals aged below the full pensionable age of 65 years remain eligible for means-tested Social Assistance benefits. Compared to the baseline where the 2007 tax, transfer and pension systems are applied to the 1982 birth cohort (see the top panel of Table 6), all three reforms lead to higher employment, and increase average per-person net Government revenue. Comparing the three reforms, the largest increase in revenue occurs following complete elimination of the Unemployment Insurance system, reflecting that this reform cuts the benefits paid to unemployed individuals and, by restricting pension point accumulation opportunities, reduces the value of pension benefits. Depending on the reform, the increase in revenue is only 9-27% of the average per-person deficit of 66095 Euros generated by a 6.4 year increase in age 65 life expectancy. Reforms that offset the fiscal cost of the increase in life expectancy expected to occur between the 1942 and 1982 birth cohorts must, therefore, be more substantial than cuts to Unemployment Insurance or disability pension benefits.

Table 6: Transfer and pension reforms: Effects for the 1982 birth cohort.

Full pensionable age (years)	Cut in pension value	Net Gov. Revenue	Years of emp.> 40	Ret. Age	Assets at age 65	Welfare (average value of reform, 100 $\times\overline{\psi}$)
Baseline: 2007 tax, transfer and pension systems						
65	0%	-93	18.78	62.69	27744	-
Focused transfer and public pension reforms (non-revenue-neutral reforms)						
Unemployment Insurance-eligible unemployed individuals no longer receive pension points:						
65	0%	12225	19.01	63.85	30364	-1.29
Unemployment Insurance completely eliminated:						
65	0%	18029	19.12	63.69	32020	-1.56
Right to early retirement on grounds of disability eliminated:						
65	0%	6091	18.87	63.41	25075	-0.98
Revenue neutral reforms to pension age thresholds and pension benefits						
65	26.8%	66002	18.95	63.90	37475	-8.51
66	20.7%	66002	19.66	64.34	34835	-5.37
67	12.4%	66002	20.44	64.91	32208	-2.01
68	5.6%	66002	21.15	65.52	29901	1.04
68.78	0%	66002	21.74	65.97	28132	3.44

Notes: Revenue-neutral reforms are calibrated to obtain an average net Government revenue per person of 66002 Euros, i.e., the average net Government revenue per person for the 1942 birth cohort given the 2007 tax, transfer and pension systems (see Table 5).

5.2.2 Revenue Neutral Reforms to Pension Age Thresholds and Pension Benefits

Next, we identify public pension reforms that obtain revenue neutrality via a combination of an increase in the pension age thresholds and a cut in the per-year value of pension benefits. "Revenue-neutral" here means restoring average net Government revenue to 66002 Euros per person, the same level as for the 1942 birth cohort when faced with the 2007 tax, transfer and pension systems. Cuts in the per-year value of public pension benefits are operationalized through adjustments in the proportionality factor that links weighted pension points to the per-year value of pension benefits. Meanwhile, an increase in the pension age thresholds entails an increase in the full pensionable age, and an equal increase in the age thresholds that govern early retirement opportunities, financial rewards for delayed retirement, and financial penalties for early retirement.[28] As increases in the per-year value of pension benefits and reductions in pension age thresholds do not feature strongly in the debate on pension reform we exclude such reforms from this analysis. Under all considered pension systems, individuals continue to accumulate weighted pension points as per the 2007 rules.

When increasing the pension age thresholds we take the view that employment opportunities will continue to be linked closely to the public pension system; in our analysis the age effects in the job offer and involuntary separation probabilities are shifted by the increase in the full pensionable age. This approach is in line with the current legislation in which employment contracts end by default when the employee reaches the full pensionable age (see Section 2.4.2). Similarly, when

[28]In a related set of policy simulations, we identified public pension reforms that obtain revenue neutrality via a combination of an increase in the full pensionable age and a cut in the per-year value of pension benefits (in these reforms all age pension thresholds except the full pensionable age are held fixed that their 2007 values). For a given full pensionable age, the revenue neutral cut in the pension generosity is very similar to that reported in Table 6. Implications for employment and welfare also do not depend strongly on whether all pension age thresholds are increase or only the full pensionable age is increased.

increasing the pension age thresholds, the age effects in wages are shifted by the increase in the full pensionable age.[29]

The bottom panel of Table 6 details revenue neutral combinations of increases in the pension age thresholds and cuts in the per-year value of pension benefits. At the two extremes, a 3.76 year increase in all pension age thresholds (a change that entails an increase in the full pensionable age from 65 years to 68.76 years) and a cut in the per-year value of public pension benefits of 26.8% both neutralize the effect on the Government's deficit that results from the 6.4 year increase in age 65 life expectancy. These two revenue-equivalent policies have dramatically different implications for labor supply and retirement behavior, wealth accumulation and welfare. Reinstating the Government's budgetary position by increasing the pension age thresholds leads to a higher average retirement age and more years of employment post age 40 years, as compared to if the Government's budgetary position is reinstated by cutting the per-year value of public pension benefits. However, cutting the per-year value of public pension benefits has a larger effect on wealth accumulation than does increasing the pension age thresholds.

The small responses of employment and retirement to a cut in the per-year value of public pension benefits partly reflect that this reform impacts high-wage individuals the most. Such individuals are likely to be employed if feasible, and, with no flexibility in hours, are generally unable to increase employment. Furthermore, for a non-retired individual a cut in the per-year value of public pension benefits has an ambiguous effect on the opportunity cost of time and, therefore, on employment and retirement incentives: a cut in the per-year value of public pension benefits reduces expected income in retirement while simultaneously cutting the future returns to current employment - the associated income and substitution effects work in opposite directions.

The substantial increase in average retirement age elicited by an increase in the pension age thresholds suggests that the rules that control access to public pension benefits, or the demand side of the labor market, or both, place constraints on behavior. To explore the relative importance of the pension rules and demand side factors we conducted a further set of simulations in which all pension age thresholds are increased by 3.76 years from their 2007 values while employment opportunities and wages are held at their pre-reform levels. Following this reform the average age of retirement increases by 1.31 years or 38% of the 3.28 year increase in the age of retirement obtained when the demand side of the labor market adjusts in line with the full pensionable age. We therefore conclude that both the pension age thresholds and the relationship between the pension system and the labor market are important determinants of behavior.

In terms of welfare, on average individuals place a value of 3.44% of baseline consumption on the reform that obtains revenue neutrality by a 3.76 year increase in the pension age thresholds. Meanwhile, on average individuals are willing to forgo 8.51% of baseline consumption to avoid an alternative reform in which revenue neutrality is obtained through a cut of 26.8% in the per-year value of pension benefits. A comparison of welfare effects across the revenue neutral reforms presented in the bottom panel of Table 6 shows that the reform that maximizes our measure of

[29] An ancillary analysis, not reported, showed that if instead the demand side of the labor market is unaffected by changes in the full pensionable age then revenue neutrality cannot be achieved purely by an increase in the pension age thresholds. Two factors contribute to this result: employment opportunities for individuals aged 65 years and above are limited and therefore the employment responses elicited by increases in the pension age thresholds are small; and increases in the pension age thresholds increase the opportunities for Unemployment Insurance-eligible unemployed individuals to accumulate pension points and thus increase annual pension benefits in retirement.

welfare is a corner solution in which the entire fiscal cost of the increase in life expectancy is offset by a 3.76 year increase in the pension age thresholds. The intuition is as follows. As the pension age thresholds are increased, individuals are made worse-off by the additional restrictions on access to public pension benefits. At the same time, individuals are made better-off by the improvement in employment opportunities that arises from a higher job offer rate and a lower involuntary separation rate. In our setting, the latter effect dominates. As an alternative measure of welfare, we compute the percentage of individuals who gain from the reform (gainers are defined as those individuals with strictly positive valuations of the reform). We find that 87.7% of individuals are made better-off when the pension age thresholds are increased by 3.76 years. In contrast, only 1.1% of individuals are made better-off when revenue neutrality is obtained by a cut of 26.8% in the per-year value of pension benefits.[30]

5.2.3 Further Insights on the Optimal Pension System

A Government's ability to increase the pension age thresholds while maintaining a strong link between the demand side of the labor market and the pension system will be limited by the physical ability of the older members of the workforce. Our model is not well-suited to understanding this issue as we do not use information on the health status of the elderly. Therefore, to say more about the optimal public pension system we fix the full pensionable age at 68.76 years, and compare the welfare implications of several reforms that involve changes to the non-age related dimensions of the pension systems. We restrict attention to reforms that are revenue neutral in the sense that they produce an average net Government revenue of 66002 Euros per person.[31] In this way, we abstract from the extent to which it is feasible to increase the pension age thresholds, and instead focus on the welfare implications of other dimensions of the public pension system.

We searched for the public pension system that maximizes our measure of welfare by considering all combinations of: pension caps of 3000, 2000, 1500, 1300, 1200, 1100, 1050 and 1000 Euros per month; pension floors of 0, 500 550 575 600 700 and 800 Euros per month; down-weights on the pension points accumulated by Unemployment Insurance-eligible unemployed individuals of 100%, 50% and 0%; and cuts in the probability of access to retirement on grounds of disability of 100%, 50% and 0%. For each combination of the policy parameters, we imposed revenue neutrality by an appropriate choice of the proportionality factor.

Among the considered revenue-neutral public pension systems with a full pensionable age of 68.76 years, the system that maximizes our measure of welfare is characterized by upper and lower pension thresholds of 1100 Euros and 550 Euros per month (year 2000 prices) respectively, elimination of pension point accumulation rights for Unemployment Insurance-eligible unemployed individuals, and elimination of the disability pension. The value attached to pension points, i.e., the proportionality factor, in this alternative system is 183% of the value under the 2007 pension system. In this system, individuals work for an average of 22 years after age 40 years, and the average age of retirement is 66.93 years. This reform is valued at an average of 8.4% of baseline consumption - more than double the average value attached to the reform in which revenue neutrality is achieved via only an increase in the pension age thresholds.

[30] An individual can be made better-off by a cut in benefits as our measure of welfare does not allow discounting due to subjective time preference.

[31] In this analysis, all pension age thresholds are increased by 3.76 years relative to the 2007 pension system.

Relative to the current system, the public pension system that maximizes our measure of welfare provides more generous benefits to individuals with low levels of experience, while limiting the pension benefits payable to individuals with high pension entitlement. Together with the cutbacks in pension point accumulation opportunities for the unemployed and increased restrictions on access to disability pension benefits, the optimal public pension system involves stronger labor supply incentives for those with, *ex ante*, the lowest propensity to work.

6 Conclusion

Using a rich dynamic structural life-cycle model estimated using Indirect Inference, this paper has provided new insights into the effect of life expectancy on life-cycle behavior. Furthermore, by recognizing the dependency between life-cycle behavior, life expectancy, and the public pension system, we have demonstrated how public pensions systems can be reformed effectively to ensure financial viability despite increasing life expectancy. Our results contain several lessons for policy makers contemplating public pension reforms. At the highest level of generality, our analysis speaks to the particular importance of determining the severity of public pension reforms specifically for individuals who are able, forced or inclined to adjust behavior in response to the reform. For example, our results show that, in the case of Germany, positive employment effects are obtained when the age-based eligibility thresholds for public pension benefits are increased but not when the per-year value of public pension benefits is cut. This result reflects that the age-based eligibility rules are binding constraints for many individuals. Meanwhile, cuts in the per-year value of public pension benefits are felt most by individuals with limited scope to increase work intensity due to strong *ex ante* attachment to the labor market.

Beyond making a significant contribution to the current policy debate on public pension reform, this paper has provided several insights regarding the analysis of individual behavior over the life-cycle. Notably, we have shown that the incentives created by the pension system are important for explaining individuals' life-cycle employment, retirement and consumption decisions. We conclude, therefore, that a detailed depiction of the pension system should be central to the modeling of many aspects of life-cycle behavior. Perhaps more importantly, our results show that life expectancy has quantitatively meaningful implications for optimal behavior prior to the full pensionable age. Our analysis thus suggests that an accurate understanding of the fiscal and behavioral implications of improving longevity requires a life-cycle approach that permits behavioral responses in terms of employment, retirement and consumption. Life-cycle modeling has been used previously to understand the implications of life expectancy for decisions related to wealth accumulation. This paper has explored the dependence of employment and retirement decisions, as well as consumption choices, on life expectancy. Therefore, our results extend previous research along an important dimension.

Our analysis relies on several assumptions and restrictions that may have implications for the policy conclusions. The focus on single-adult households is a case in point. Single individuals do not have access to income from a spouse, and single women tend to work more than their cohabiting counterparts. Despite these differences, we argue that our results are likely to hold, at least in spirit, for the full population. In particular, the differences in employment and retirement behavior between single and cohabiting individuals are small relative to the pronounced changes in behavior over the life-cycle that are present for both groups. This suggests that age-related policies and common life-cycle factors are likely to outweigh household-type effects in driving behavior (consistent with this, Kimmel and Kniesner, 1998, find little variation in the wage elasticity of hours worked by the employed according to marital status, and find much more variation in the wage elasticity of labor force participation by gender). Cohabiting individuals further differ from singles in that they have higher life expectancy (see, e.g., Hu and Goldman, 1990). However, our policy analysis centers around mitigating the fiscal effects of changes in life expectancy, and therefore any level differences in life expectancy by household type should not invalidate the applicability of our analysis to couple households. Based on a sample of ten developed countries, excluding Germany, Valkonen et al. (2004) provide mixed evidence of differential trends in life expectancy by household type. We are not aware of any similar studies for Germany.

Further, we have not considered interactions between life expectancy and health-care costs. The fiscal neutrality of the pension reforms identified herein is likely to be challenged by increasing health-care costs. Finally, we stress that our analysis holds fertility constant. Offsetting the fiscal cost of an increase in life expectancy would require more aggressive public pension reforms in a world of declining fertility. For Germany, declining fertility is a huge concern and a comprehensive study to identify pension systems that are robust to declining fertility would be of great importance. In the interim, we believe the tradeoffs identified in our analysis are relevant to the design of pension reforms targeted specifically at mitigating the fiscal cost of declining fertility.

Appendix

A Value Function Approximation

We approximate the value function using recursive simulation and interpolation, as introduced by Keane and Wolpin (1994). We work backwards from time T, last period in which the individual may be employed, i.e., age 64.75 in the estimation and age 79.75 in the counterfactual analysis. We start with a set of randomly selected grid of points, where each grid point represents a particular combination of age T state variables (p_T), an age T employment outcome (d_T) and an age T consumption choice (c_T). We evaluate $\mathrm{E}_T[V^r_{T+0.25}(p_{T+0.25})|p_T, d_T, c_T]$, the value function for retirement at time $T + 0.25$, at each age T grid point. Given the process for consumption in retirement described in equation (9) and the distributional assumptions outlined in Section 2.1, we have an analytic expression for this value function. Parameters from an Ordinary Least Squares (OLS) regression are used to express the expected age $T + 0.25$ value function in terms of variables known to the individual at age T. This OLS regression, as well as those used in later value function approximations, includes a total of 143 regressors and is implemented using a grid containing 5000 points.

At the next stage of the value function approximation, we move back one quarter to age $T - 0.25$ years and select grid of $(d_{T-0.25}, c_{T-0.25}, p_{T-0.25})$ points. For each grid point we use Monte Carlo simulation together with our distributional assumptions to approximate $\mathrm{E}[V_T(p_T)|d_{T-0.25}, c_{T-0.25}, p_{T-0.25}]$ at the values of $(p_{T-0.25}, d_{T-0.25}, c_{T-0.25})$ appearing in the chosen grid. The objects to be approximated appear in square brackets in equations (11), (13) and (14).

In more detail, we approximate the expectation of next period's value function as follows: i) we update all grid points that correspond to state variables (except those pertaining to the transient unobservables in preference) based on the relevant equations of motion; ii) for $j = f, u$ we determine the consumption level that satisfies equation (15) and we compute the consumption level in retirement based on equation (9); iii) we use the type I extreme value assumption to evaluate the expected maximums and expected values of the future value functions, thereby integrating out future preference shocks from the value function; iv) we combine quantities obtained at step iii) with the job offer and involuntary separation probabilities to form a draw from the distribution of the expectation next period's value function; v) we repeat steps i)-iv) several times, each time using a different draw from the distribution of next period's state variables; and vi) we approximate the value function at each age $T-0.25$ grid point by the average of the draws from the distribution of expectation of next period's value function.

Again, parameters from an OLS regression are used to express the expected age T value function in terms of variables known to the individual at age $T - 0.25$. We work backwards in this way until age 40, with the OLS approximation to next period's values function being used to compute the value function for the current period. To ensure we capture the year-specific aspects of the fiscal legislation, this entire procedure is repeated for each of the 17 different tax and transfer systems operational during the sample period.

Consumption, or equivalently, savings, is a continuous choice variable and therefore we must discretize the choice set. We achieve this by restricting attention to the following choices: i) employment in conjunction with savings of -500, 0, 250, 500, and 1000 Euros per month; ii) unemployment in conjunction with savings of -2000, -1000, -500, 0, and 250 Euros per month; and (iii) retirement. We construct the choice set to over-represent dissaving combined with unemployment and saving combined with employment because empirically these are the most prevalent combinations of savings and labor supply choices.[32]

B Tax and Transfer Systems: Additional Details

An employed individual's net income is computed by applying to gross income the appropriate deductions for Social Security Contributions and income tax. Social Security Contributions are made for health, pension and Unemployment Insurance benefits, and are obligatory. Social Security Contributions are payable at a constant rate on all gross wage income above a disregard and below an earnings cap. In addition to the employee's Social Security Contributions, the employer pays the same amount in Social Security Contributions (since July 2005 there has been a small divergence from this rule which we neglect in this study). Income tax is payable at a rate that is increasing in the individual's taxable income. Taxable income, in turn, consists of any gross

[32]The specification of the consumption grid appears reasonable: at the estimated parameters, only 1.3% of employed individuals choose to save the maximum permitted amount of 1000 Euros, only 0.6% of unemployed individuals choose the dissave to maximum permitted amount of 2000 Euros and, consistent with observed behavior, most savings choices are at or close to zero. We demonstrate robustness of our results to the specification of the consumption grid by re-estimating the structural parameters with the choice set extended to include more alternatives with low saving or low dissaving. Specifically, we additionally allow employment and unemployment each in conjunction with savings of -250 and 125 Euros per month. The resulting estimates of the subjective time discount factor and the CRRA, two parameters linked closely to the wealth accumulation process, are both less than one standard deviation different from the values obtained in the primary estimation.

income in excess of the sum of the universal tax-free allowance and permissable Social Security Contributions.

An unemployed individual's net income is computed by adding to gross income any transfer payments from the Government and applying the appropriate deduction for income tax. In Section 2.1 we outlined the defining features of Social Assistance and Unemployment Insurance. We additionally note here that Social Assistance benefits have no tax implications. Meanwhile, Unemployment Insurance is not directly taxed. Instead, Unemployment Insurance is added to interest income and the individual's average tax rate is determined based on the same tax schedule as applicable to employed individuals. The individual's tax liability is determined by applying the individual-specific average tax rate to interest income. See Table 9 in Haan and Prowse (2011) for further details.

We note here two further features of income tax that apply irrespective of an individual's labor market status. First, only interest income from wealth in excess of a disregard counts towards taxable income. Second, there exists a Solidarity tax, introduced to finance the cost of German reunification. The Solidarity tax is proportional to an individual's income tax liability. Currently, there is no indication that the Solidarity tax will be phased out.

C Further Details on Estimation Strategy and Identification

C.1 Initial Conditions

In the spirit of Heckman (1981), we use a reduced form model to approximate behavior prior to the initial period of observation. We allow the persistent unobservables that appear in the structural model to enter the reduced form model of the initial conditions. Thus, the initial values of the endogenous variables may be endogenous with respect to the unobservables that drive later behavior.

In more detail, we use a dynamic multinomial logit model to approximate employment and retirement outcomes for each individual in each quarter between leaving full-time education and entering the sample. The payoffs in the multinomial logit model depend on observed individual characteristics, the quarter-specific wage, cohort effects, and the permanent unobservables that feature in preferences and in the job offer and involuntary separation probabilities. Quarter-specific wages are obtained by taking draws from the distribution of offered wages as described by the structural parameters. Using the simulated pre-sample employment outcomes and wages we are able to construct each individual's experience, Unemployment Insurance entitlement period and weighted pension points at the time when the individual enters the sample. Finally, we simulate initial wealth by drawing from a log normal distribution with a common variance and a mean that depends on initial experience, initial employment status, age, gender, education and region of residence.

Marital status and household structure prior to the individual entering the sample perform the role of exclusion restrictions, that is variables that affect the initial conditions but which, conditional on initial behavior, do not affect outcomes during the sample period. Our estimation results show the exclusions restrictions in the initial employment equation are jointly significant (χ^2 test; $p = 0.010$). See the notes to Table 8 for further details.

C.2 Construction of Simulated Samples and Treatment of Missing Wages

The construction of each of the K simulated samples starts from the empirical distribution of the exogenous individual characteristics, such as gender and education, observed in the SOEP-HMD estimation sample. For a given value of the structural parameters θ, we simulate initial values of the endogeneous variables using a reduced form model (see Appendix C.1). We then simulate wage offers and employment, retirement and consumption outcomes in subsequent quarters of the sample period based on the above-described structural model. The value function is approximated using the simulation and interpolation method described in Appendix A. When estimating the structural parameters we generate $K = 5$ simulated samples - in total we simulate the behavior of around 12000 hypothetical individuals in approximately 200000 time periods.

Health, measured by an indicator of the individual reporting health problems that limit daily activities, enters the model as a stochastic and exogenous state variable. We estimate the parameters of an equation of motion for health in which current health problems are function of health status in the previous period, age and demographic variables.[33] The parameters from this initial estimation are used to simulate the evolution of health problems when constructing the simulated samples.

Recall, we sample wages only in quarters that coincide with the administration of the annual SOEP survey and only for employed individuals who answer all required survey questions. We replicate this selection process when constructing the simulated samples, and in doing so we account for selectivity in wages. In more detail, a simulated wage draw is recorded in a simulated sample, and therefore is used when estimating the auxiliary model parameters, if and only if: i) employment is the individual's optimal choice in the simulated sample; ii) the quarter is one in which the individual was surveyed; and iii) the observation survived a selective process of elimination of accepted wage draws designed to account for non-random non-response.[34] Non-labor income and non-linearities in the tax and transfer schedules provide exclusion restrictions and thus ensure identification of the wage parameters is not reliant purely on functional form.

C.3 Further Econometric Details

The Indirect Inference estimator $\widehat{\theta}_N^K$ was defined by equation (16) in Section 4. Let θ_0 denote the true value of the structural parameters. Let F denote the distribution of the exogenous variables (including unobservables) and let $Q_\infty(F, \theta, \gamma)$ denote the limit as $N \longrightarrow \infty$ of the criterion function from which the auxiliary model parameters are estimated. Define the binding function $g(F, \theta) = \text{argmax}_\gamma \; Q_\infty(F, \theta, \gamma)$. Define $D = \partial g(F_0, \theta_0)/\partial\theta'$ and $C = V_{AS}\left[\sqrt{N}\left(\gamma - \frac{1}{K}\sum_{k=1}^{K}\gamma_k^s(\theta_0)\right)\right]$, where V_{AS} denotes the asymptotic variance and F_0 and θ_0 denote the true distribution of exogenous variables and true values of structural parameters

[33]The parameters of the health equation are estimated using an Indirect Inference routine that seeks to match selected OLS coefficients from a regression of current health on region, gender, cohort-gender interactions, cohort-region interactions and health one year ago (the cohort variable is the difference between the individual's year of birth and 1930). We do not attempt to match the coefficients on the cohort terms, and therefore we are effectively purging the self-reported health variable of gender-specific and region-specific cohort effects.

[34]We estimate the effect of observed characteristics on the probability of an employed individual refusing to answer one or more of the survey questions required to construct the hourly wage. We then exclude the simulated wage draws of employed individuals with the same probability. This method assumes that survey non-response is based purely on observables.

respectively. Assume $W_N \xrightarrow{p} W$ as $N \to \infty$ where W is a deterministic positive definite matrix. Under the conditions in Gourieroux et al. (1993) we have

$$\sqrt{N}\left(\widehat{\theta}_N^K - \theta_0\right) \underset{N\to\infty}{\longrightarrow} N\left(0, \left(1+\frac{1}{K}\right)(D'WD)^{-1}(D'WCWD)(D'WD)^{-1}\right). \qquad (21)$$

Our specification of the weighting matrix W_N has diagonal elements equal to the inverse of the variances of the auxiliary model parameters and zeros elsewhere. We estimate the variances appearing in the weighting matrix by: i) constructing 5000 bootstrap samples from our SOEP-HMD estimation sample; ii) estimating the auxiliary model parameters using each of the 5000 bootstrap samples; and iii) computing the variance of the estimated auxiliary model parameters over the 5000 bootstrap samples. Each bootstrap sample is constructed by sampling with replacement from the original SOEP-HMD estimation sample with clustering at the individual level and stratification according to panel length. The latter restriction ensures the cross-sectional and longitudinal dimensions of each bootstrap sample match that of the SOEP-HMD estimation sample.

Table 7 describes the auxiliary model parameters and indicates which of the structural parameters are primarily identified by each set of auxiliary model parameters.

Table 7: Summary of auxiliary model parameters.

Description of auxiliary model parameters	Number of parameters	Primarily identifying
Coefficients from regressions of wealth on age dummies and wealth on dummies for gender-region combinations	29	Subjective time discount factor (δ) and utility curvature parameter (ρ)
Coefficients from a regression of annual wealth change on age	2	As above
Coefficient on life expectancy from a regression of an indicator of retirement on life expectancy and controls for gender and region, a gender-region interaction, and dummies for cohort, age and time (see Specification 1 in Table 2)	1	As above
Coefficients from a regression of log wages on experience, health problems, indicator of initial employment, region, education, nationality, gender and age terms	14	Distribution of offered wages
Coefficients from quantile regressions of log wages and changes in log wages on intercepts, estimated at the 20th, 40th, 60th and 80th percentiles; Autocorrelation coefficients obtained from regressions of standardized log wages on standardized log wages lagged one, two and three years	19	As above
Treatment effects obtained from regressions of transitions between labor market states on the change in UI entitlement period caused by the 1997 UI reform (see Haan and Prowse, 2010)	20	Coefficient on consumption (β)
Coefficients on indicator of initial employment from regressions of indicators of employment and retirement on indicator of initial employment	2	Variance of complementarity between consumption and leisure (σ_η)
Coefficients from regressions of indicators of various sequences of labor market outcomes on intercepts (e.g., estimated intercept from regression of indicator of being in full-time work at time t, $t-0.25$ and $t-0.5$ on intercept)	18	Parameters appearing in the job offer and involuntary separation probabilities
Coefficients from regressions of indicators of employment and retirement on age dummies	50	Mean of the complementarity parameter (μ_η) and age effects in the job offer and involuntary separation probabilities
Coefficients from regressions of the individual-specific numbers of transitions from unemployment to employment and from employment to unemployment on initial employment state; Correlation coefficient obtained from of regression of standardized individual-specific number of transitions into employment on standardized individual-specific number of transitions out of employment	3	Variance-covariance matrix of the individual-specific unobservables in the job offer and involuntary separation probabilities (Σ^η)
Coefficients from regressions of transitions from unemployment to employment and from unemployment to retirement on experience, health problems, UI entitlement period, region, and age terms	30	Parameters determining eligibility for early retirement on the grounds of disability
Coefficients from regressions of transitions from employment to unemployment and from employment to retirement on experience, health problems, UI entitlement period, region, and age terms	28	As above
Coefficients from regressions of indicator of initial employment and indicator of initial retirement on initial experience, health problems in initial period, gender, region, education, nationality, children, martial status, age terms and cohort effects	38	Parameters describing initial employment and initial retirement (see Appendix C.1)
Coefficients from a regression of initial wealth on indictor of initial employment, initial experience, gender, region and age terms; Standard deviation of initial wealth	11	Parameters describing initial wealth (see Appendix C.1)

Notes: Unless indicated otherwise, regressions are estimated using Ordinary Least Squares and include intercepts. Standardization entails subtracting the variable's sample mean and dividing by the variable's sample standard deviation. "Region" is an indicator of the individual residing is west Germany. "Gender" is an indicator of the individual being male. "Education" refers to years of education. "Nationality" is an indicator of the individual being a native German. "Children" and "marital status" are indicators of, respectively, the individual having had dependent children prior to entering the sample and having been married prior to entering the sample. "UI" is an abbreviation for Unemployment Insurance.

D Parameters of Initial Conditions

Table 8: Estimates of parameters appearing in the initial conditions.

	Coefficient	Standard Error
Initial Employment		
Intercept	1.943	0.348
$\min(\text{Age} - 40, 15)\text{I}(\text{Age} \geq 40)/15$	-2.031	0.399
$(\text{Age} - 55)\text{I}(\text{Age} \geq 55)/15$	-4.990	0.830
log(gross offered wage)	2.605	0.453
Permanent unobserved individual preference shifter	2.717	0.649
Permanent unobserved individual effect appearing in involuntary separation prob.	0.002	0.147
Permanent unobserved individual effect appearing in job offer prob.	-2.694	0.349
Male	0.211	1.074
West	0.109	0.693
West × Male	0.100	1.464
Education (years)/10	1.763	0.484
Year of birth × West × Male	-0.443	0.534
Year of birth × West × Female	0.215	0.586
Year of birth × East × Male	0.449	1.046
Year of birth × East × Female	0.946	1.230
Native German	-0.494	0.359
Previously been married†	0.207	1.115
Previously had children†	0.350	1.273
Previously been married × West†	-0.951	0.965
Previously been married × Male†	-0.590	0.725
Previously had children × West†	-0.226	1.255
Initial health problems	-1.637	0.383
Initial Retirement		
Intercept	-3.374	0.267
$\min(\text{Age} - 54, 4)\text{I}(\text{Age} \geq 54)/5$	0.115	0.621
$(\text{Age} - 58)\text{I}(\text{Age} \geq 58)/5$	2.723	0.367
Male	-0.770	0.665
West	-1.283	0.408
West × Male	1.192	0.758
Year of birth × West × Male	0.516	0.651
Year of birth × West × Female	1.163	0.480
Year of birth × East × Male	-1.949	3.344
Year of birth × East × Female	0.264	0.799
Initial health problems	1.901	0.385
Initial Wealth		
Intercept	7.375	0.135
$\min(\text{Age} - 40, 15)\text{I}(\text{Age} \geq 40)/10$	0.969	0.168
$\min(\text{Age} - 55, 4)\text{I}(\text{Age} \geq 55)/5$	0.353	0.180
$(\text{Age} - 60)\text{I}(\text{Age} \geq 60)/5$	0.315	0.210
Male	-0.161	0.237
West	1.156	0.155
West × Male	0.376	0.268
Education (years)/10	1.096	0.142
Initial experience	0.110	0.210
Initially employed	0.432	0.121
σ_{Wealth}	1.169	0.033

Notes: †denotes an exclusion restriction. The exclusion restrictions in the initial employment equation are jointly significant (χ^2 test; $p = 0.010$). "Initial health problems" is an indicator of an individual having health problems that limit daily activities in the initial period of observation.

References

Adda, J., **Dustmann, C.**, and **Stevens, K.** (2011). The Career Costs of Children. *CEPR Discussion Paper Number 8697*

Alesina, A. and **Fuchs-Schuendeln, N.** (2007). Good Bye Lenin (Or Not?): The Effect of Communism on People's Preferences. *American Economic Review*, 97(4): 1507–1528

Altonji, J., **Smith, A.**, and **Vidangos, I.** (2009). Modeling Earnings Dynamics. *NBER Working Paper*, No. 14743

Baker, M., **Stabile, M.**, and **Deri, C.** (2004). What Do Self-Reported, Objective, Measures of Health Measure? *Journal of Human Resources*, 39(4): pp. 1067–1093

Blau, D. (1994). Labor Force Dynamics of Older Men. *Econometrica*, 62(1): 117–156

Blöndal, S. and **Scarpetta, S.** (1997). Early Retirement in OECD Countries: The Role of Social Security Systems. *OECD Economic Studies*, 29: 7–54

Blundell, R., **Meghir, C.**, and **Smith, S.** (2002). Pension Incentives and the Pattern of Early Retirement. *Economic Journal*, 112(478): C153–C170

Bonin, H. (2009). 15 Years of Pension Reform in Germany: Old Successes and New Threats. *Geneva Papers on Risk and Insurance*, 34(4): 548–560

Brown, J. (2001). Private Pensions, Mortality Risk, and the Decision to Annuitize. *Journal of Public Economics*, 82(1): 29–62

Börsch-Supan, A. and **Schnabel, R.** (1998). Social Security and Declining Labor-Force Participation in Germany. *American Economic Review: Papers and Proceedings*, 88(2): 173–178

Börsch-Supan, A. and **Wilke, C.** (2004). The German Public Pension System: How it Was, How it Will Be. *NBER Working Paper 10525*

Casanova, M. (2010). Happy Together: A Structural Model of Couples' Joint Retirement Choices. *Mimeo*

De Nardi, M., **French, E.**, and **Jones, J.** (2009). Life Expectancy and Old Age Savings. *American Economic Review: Papers and Proceedings*, 99(2): 110–115

De Nardi, M., **French, E.**, and **Jones, J.** (2010). Why do the Elderly Save? The Role of Medical Expenses. *Journal of Political Economy*, 118(1): 39–75

Disney, R. and **Smith, S.** (2002). The Labour Supply Effect of the Abolition of the Earnings Rule for Older Workers in the United Kingdom. *Economic Journal*, 112(478): C136–C152

Eckstein, Z. and **Wolpin, K.I.** (1989). Dynamic Labour Force Participation of Married Women and Endogenous Wage Growth. *Review of Economic Studies*, 56(3): 375–390

French, E. (2005). The Effects of Health, Wealth, and Wages on Labour Supply and Retirement Behaviour. *Review of Economic Studies*, 72(2): 395–427

French, E. and **Jones, J.** (2012). Public Pensions and Labor Supply over the Life Cycle. *International Tax and Public Finance*, 19(2): 268–287

French, E. and **Jones, J.** (2011). The Effects of Health Insurance and Self-Insurance on Retirement Behavior. *Econometrica*, 79(3): 693–732

Friedberg, L. (2000). The Labor Supply Effects of the Social Security Earnings Test. *Review of Economics and Statistics*, 82(1): 48–63

Friedberg, L. and **Webb, A.** (2005). Retirement and the Evolution of Pension Structure. *Journal of Human Resources*, 40(2): 281–308

Frijters, P. and **van der Klaauw, B.** (2006). Job Search with Nonparticipation. *Economic Journal*, 116(508): 45–83

Fuchs-Schuendeln, N. (2008). The Response of Household Saving to the Large Shock of German Reunification. *American Economic Review*, 98(5): 1798–1828

Fuchs-Schuendeln, N. and **Schuendeln, M.** (2005). Precautionary Savings and Self-Selection: Evidence from the German Reunification Experiment. *Quarterly Journal of Economics*, 120(3): 1085–1120

Gan, L., **Gong, G.**, **Hurd, M.**, and **McFadden, D.** (2004). Subjective Mortality Risk and Bequests. *NBER Working Paper*, 10789

Garibaldi, P. and **Wasmer, E.** (2005). Equilibrium Search Unemployment, Endogenous Participation, and Labor Market Flows. *Journal of the European Economic Association*, 3(4): 851–882

Gjonça, A., **Brockmann, H.**, and **Maier, H.** (2000). Old-Age Mortality in Germany Prior to and After Unification. *Demographic Research*, 3(1)

Gourieroux, C., **Monfort, A.**, and **Renault, E.** (1993). Indirect Inference. *Journal of Applied Econometrics*, 8(S1): S85–S118

Gruber, J. and **Wise, D.** (1998). Social Security and Retirement: An International Comparison. *American Economic Review: Papers and Proceedings*, 88(2): 158–163

Gruber, J. and **Wise, D.** (2004). *Social Security Programs and Retirement Around the World: Micro-estimation*. University of Chicago Press

Gruber, J. and **Wise, D.** (2007). *Social Security Programs and Retirement Around the World: Fiscal Implications for Reform*. University of Chicago Press

Gustman, A.L. and **Steinmeier, T.L.** (1986). A Structural Retirement Model. *Econometrica*, 54(3): 555–584

Gustman, A.L. and **Steinmeier, T.L.** (2005). The Social Security Early Entitlement Age in a Structural Model of Retirement and Wealth. *Journal of Public Economics*, 89(2-3): 441–463

Haan, P. and **Prowse, V.** (2010). The Design of Unemployment Transfers - Evidence from a Dynamic Structural Life-cycle Model. *Working Paper, Department of Economics, University of Oxford, 478*

Haan, P. and **Prowse, V.** (2011). Longevity, Life-Cycle Behavior and Pension Reform. IZA Discussion Paper 5858

Haveman, R., **De Jong, P.**, and **Wolfe, B.** (1991). Disability Transfers and the Work Decision of Older Men. *Quarterly Journal of Economics*, 106(3): 939–949

Heckman, J. (1981). Statistical Models for Discrete Panel Data. In C.F. Manski and D. McFadden, editors, *Structural Analysis of Discrete Data with Econometric Applications*, 114–178. MIT Press

Heyma, A. (2004). A Structural Dynamic Analysis of Retirement Behaviour in the Netherlands. *Journal of Applied Econometrics*, 19(6): 739–759

Hu, Y. and **Goldman, N.** (1990). Mortality Differentials by Marital Status: An International Comparison. *Demography*, 27(2): 233–250

Hurd, M. (1989). Mortality Risk and Bequests. *Econometrica*, 57(4): 779–813

Hurd, M. and **McGarry, K.** (2002). The Predictive Validity of Subjective Probabities of Survival. *Economic Journal*, 112(482): 966–985

Imai, S. and **Keane, M.P.** (2004). Intertemporal Labor Supply and Human Capital Accumulation. *International Economic Review*, 45(2): 601–641

Jacobzone, S., **Cambois, E.**, and **Robine, J.** (2000). Is the Health of Older Persons in OECD Countries Improving Fast Enough to Compensate for Population Ageing. *OCED Economic Studies*, 30(1): 149–190

Jiménez-Martín, S. and **Sanchez Martín, A.** (2007). An Evaluation of the Life Cycle Effects of Minimum Pensions on Retirement Behavior. *Journal of Applied Econometrics*, 22(5): 923–950

Keane, M.P. and **Wolpin, K.I.** (1994). The Solution and Estimation of Discrete Choice Dynamic Programming Models by Simulation and Interpolation: Monte Carlo Evidence. *Review of Economics and Statistics*, 76(4): 648–672

Keane, M.P. and **Wolpin, K.I.** (2001). The Effect of Parental Transfers and Borrowing Constraints on Educational Attainment. *International Economic Review*, 42(4): 1051–1103

Keane, M.P. (2011). Labor Supply and Taxes: A Survey. *Journal of Economic Literature*, 49(4): 961–1075

Keane, M.P. and **Wolpin, K.I.** (1997). The Career Decisions of Young Men. *Journal of Political Economy*, 105(3): 473–522

Kibele, E. and **Scholz, R.** (2008). *Trend der Mortalitätsdifferenzen in Ost und West unter Berücksichtigung der vermeidbaren Sterblichkeit*, 125–140. VS Verlag für Sozialwissenschaften

Kimmel, J. and **Kniesner, T.** (1998). New Evidence on Labor Supply: Employment Versus Hours Elasticities by Sex and Marital Status. *Journal of Monetary Economics*, 42(2): 289–301

Kroh, M. and **Spieß, M.** (2008). Documentation of Sample Sizes and Panel Attrition in the German Socio Economic Panel (SOEP) (1984 until 2007). *SOEP Data Documentation*, 27

Lalive, R., **van Ours, J.**, and **Zweimüller, J.** (2006). How Changes in Financial Incentives Affect the Duration of Unemployment. *Review of Economic Studies*, 73(4): 1009–1038

Low, H., **Meghir, C.**, and **Pistaferri, L.** (2010). Wage Risk and Employment Risk over the Life Cycle. *American Economic Review*, 100(4): 1432–1467

Meghir, C. and **Pistaferri, L.** (2004). Income Variance Dynamics and Heterogeneity. *Econometrica*, 72(1): 1–32

Nolte, E., **Scholz, R.**, **Shkolnikov, V.**, and **McKee, M.** (2002). The Contribution of Medical Care to Changing Life Expectancy in Germany and Poland. *Social Science & Medicine*, 55(11): 1905–1921

Oeppen, J. and **Vaupel, J.W.** (2002). Broken Limits to Life Expectancy. *Science*, 296(5570): 1029–1031

Rust, J. and **Phelan, C.** (1997). How Social Security and Medicare Affect Retirement Behavior in a World of Incomplete Markets. *Econometrica*, 65(4): 781–832

Valkonen, T., **Martikainen, P.**, and **Blomgren, J.** (2004). Increasing Excess Mortality among Non-married Elderly People in Developed Countries. *Demographic Research*, 2(12): 306–330

van der Klaauw, W. and **Wolpin, K.I.** (2008). Social Security and the Retirement and Savings Behavior of Low-Income Households. *Journal of Econometrics*, 145(1-2): 21–42

Verbrugge, L. (1984). Longer Life but Worsening Health? Trends in Health and Mortality of Middle-Aged and Older Persons. *The Milbank Memorial Fund Quarterly. Health and Society*, 62(3): 475–519

Wagner, G., **Frick, J.**, and **Schupp, J.** (2007). The German Socio-Economic Panel Study (SOEP) - Scope, Evolution and Enhancements. *Schmollers Jahrbuch*, 127(1): 139–169