Optimal Unemployment Insurance and Welfare Benefits in a Life-cycle model of Family Labor Supply and Savings

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Abstract

We specify and estimate a dynamic structural life-cycle model of labor supply, retirement and savings decisions of single-adult and couple households. Drawing on our model, we study the interplay between family labor supply and public insurance mechanisms. By including family labor supply, we recognize that the incentive effects and optimal design of public insurance programs may be impacted by a household's ability to adjust either one spouse's or both spouses' labor supply in response to wage and employment shocks. The analysis sheds new light on the optimal trade-off between insurance and incentives. In particular we show that family labor supply has quantitatively important implications for the optimal design of public insurance programs.

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1 Introduction

In this paper, we consider the incentive effects and optimal design of public insurance programs in the presence of intra-household insurance from family labor supply and savings. By including family labor supply, we recognize that the incentive effects and optimal design of public insurance programs may be impacted by a household's ability to adjust either one spouse's or both spouses' labor supply in response to wage and employment shocks. The analysis sheds new light on the optimal trade-off between insurance and incentives. In particular, based on our estimation results from a dynamic structural life-cycle model, we show that family labor supply has quantitatively important implications for the optimal design of public insurance programs.

An important literature explores empirically the insurance-incentive trade-off inherent in the design of public insurance programs. For example, see Low and Pistaferri, 2010, on Disability Insurance, French and Jones, 2011 on pensions, and Chetty, 2008, Lentz, 2009, and Low *et al.*, 2010, on Unemployment Insurance.[1] Yet, these studies focus on single individuals or households facing a single labor supply decision. We extend this work and consider the implications for incentives and optimal policy design of intra-household insurance from family labor supply.

Recent research has shown that adjustments in family labor supply are an important means of consumption smoothing.[2] Specifically, Blundell *et al.*, 2012 show that permanent shocks to men's and women's wages are mostly insured by adjustments of family labor supply. However, because the public insurance system is not modeled, their results cannot speak to the implications of household labor supply for the optimal design of public insurance programs. In contrast, we incorporate an explicit and detailed specification of the public insurance system, including Unemployment Insurance and Welfare benefits. This feature of our analysis is critical for allowing us to address questions surrounding the interplay between publicly-provided insurance from social programs and intra-household insurance from family labor supply.

Building on these related works, we are the first to look at the optimal generosity of Unemployment Insurance and Welfare benefits in the presence of family labor supply and savings. With family labor supply, the insurance-incentive trade-off is more nuanced than for households that face a single labor supply decision. On the one hand, each spouse

[1] Low, 2005, Heathcote *et al.*, 2009, discuss the insurance role of individual labor supply.

[2] Focusing on labor supply, Lundberg (l985) and Hyslop (2001) document empirically an "added worker" effect whereby a woman increases her labor supply in response to a decline in her spouse's earnings. Similarly, Cullen and Gruber (2000) demonstrate that generous Unemployment Insurance for a newly-unemployed individual reduces his or her spouse's labor supply. These results point to an important insurance role for household labor supply, however, the precise implications of household labor supply for the design of public insurance programs are not evident.

can provide insurance against shocks hitting his or her partner. On the other hand, with two potential sources of labor supply, there is greater scope for adverse incentive effects. We find that the optimal generosity of Unemployment Insurance and Welfare benefits are below their current levels. The welfare loss associated with a move to the optimal policy amounts to X Euros per person.

A further novelty of our analysis is to consider the optimal policy mix of Unemployment Insurance and Welfare benefits. In general previous work has considered the design of these institutions in isolation. However, in the family context, means testing leads to strong interactions between individual-based Unemployment Insurance and household-related Welfare benefits. This motivates our joint analysis of the design of these institutions. Our results show that...

Last, we explore how conclusions about optimal policy depend on intra-household insurance from the the ability of adjusting jointly labor supply. In particular, when we restrict the household labor supply process by excluding cross-spousal labor supply responses to individual-specific shocks we find that the optimal generosities of both Unemployment Insurance and Welfare benefits are higher. This implies that the additional intra-household insurance from family labor supply has important consequences from the optimal design of social insurance programs.

We accomplish our analysis by specifying and estimating a life-cycle model of the labor supply, retirement and savings decisions in single-adult and couple households. It is necessary to model the behavior of individuals in single and couple households to account for family formation and life-cycle transitions between marital states. In our model, the combination of job destructions and labor market frictions creates individual employment risk, and individual productivity risk enters via permanent unanticipated movements in market wages. Households may draw on intra-household and public insurance devices when hit by shocks. We model public insurance in the from of Unemployment Insurance, universal Welfare and pension benefits. We also model the intra-household insurance available from household labor supply. In couple households, the labor supply decisions of the spouses are made jointly, and therefore the spousal labor supply is a modeled source of intra-household insurance. Intra-household insurance is also provided by household savings, however, households face borrowing constraints, i.e., they are liquidity constrained, and so cannot borrow against future income when hit by shocks.

More specifically, we use a dynamic structural life-cycle model in which the constraints and incentives presented by public and intra-household insurance devices appear alongside inter-temporal incentives to accumulate human capital and to accumulate entitlements to public insurance programs. The forward-looking households in our model thus choose self-insurance and to draw on public insurance programs while simultaneously considering the implications of current behavior for expected future labor market outcomes, future self-insurance options and future entitlements to transfers from public insurance programs.

We have elected to study the interplay between public and intra-household insurance in this general life-cycle framework in part because previous work on life-cycle labor supply has shown that expected future returns to endogenously-accumulated human capital and expected future social transfers have important behavioral implications (see, e.g., Keane and Wolpin, 1997 or Blundell *et al.*, 2013 for discussion of endogenous accumulation of human capital, and see, e.g., Frederick, 2005, Low, 2005, Attanasio *et al.*, 2008, Heathcote *et al.*, 2009, Low *et al.*, 2010, and Haan and Prowse, Forthcoming for evidence on responses of benefit entitlement).

The estimation sample is constructed from a long panel of single-adult and couple households taken from the German Socio-Economic Panel (SOEP). The estimation sample contains observations of employment and retirement outcomes at a quarterly frequency, information on household composition, household-level and individual-level demographic characteristics and rich cross-sectional information on household asset holdings. Similar to Altonji *et al.* (Forthcoming), we use Indirect Inference to estimate the parameters of our structural life-cycle model. This simulation-based estimation methods centers around an auxiliary model that is used to compare the distribution of the sample observations with the distribution of an artificial sample simulated from the structural model. Indirect Inference provides a convenient framework for handling the missing observations and latent variables that appear in our estimation problem. Further, Indirect Inference circumvents the need to compute choice probabilities, which would be infeasible here, given the multiple sources of unobserved heterogeneity. Our auxiliary model provides a flexible and rich description of the distributions of households labor supply and retirement behavior, wages and assets. - maybe this is too much

The estimated model has good in-sample fit: based on the estimated model, we are able to replicate the observed life-cycle profiles of labor supply, wealth and wages. We also fit the joint distribution of spouses' labor supply and retirement outcomes and the change in this distribution with age. Further, following, e.g., Todd and Wolpin (2006) and Low and Pistaferri (2010), we conduct an external model validation exercise. Specifically, based on the estimated model, we replicate results from the reduced-form literature on the employment effects of changes in the level and duration of Unemployment Insurance (see, e.g., Katz and Meyer, 1990, Lalive *et al.*, 2006 and Schmieder *et al.*, 2012). We take this as evidence that our model is well-suited to analyzing questions surrounding the optimal design of Unemployment Insurance and Welfare benefits.

Consistent with Blundell *et al.* (2012), our results point to an important role for spousal labor supply in cushioning the impact of a job loss. Further, we show that the ability of couple households to re-optimize the labor supply of both spouses works to reduce the willingness for such households to pay for universal Welfare, relative to if re-optimization in response to the job less were restricted to the newly unemployed individual. These results have important implications for the optimal design of Unemployment Insurance and universal Welfare programs.

This paper proceeds as follows. Section 2 describes our model of households' job search, labor supply, retirement and savings decisions over the life-cycle. Section 3 details the relevant features of the SOEP survey and describes our estimation sample. Section 4 outlines the adopted Indirect Inference estimation procedure, describes the specification of the auxiliary model and details our approach to solving the dynamic programming problem. Section 5 presents the structural parameter estimates and demonstrates the model's in-sample and out-of-sample goodness of fit. Section 6 reports the results of our behavioral simulations.

2 Model

2.1 Overview

We propose a discrete-time dynamic model of the labor supply, retirement and consumption outcomes of singles individuals and couples over the life-cycle.[3] Figure 1 illustrates the timing of events over the life-cycle. Individuals enter the labor force from full-time education.[4] For those in the labor force, each period proceeds as follows: (i) household type (single-adult or couple) is updated, the household observes each member's market wage, job destruction status and retirement eligibility, and fertility outcomes are observed by the household; (ii) the household members may search for job offers; (iii) job offers arrive; and (iv) the household makes savings, job acceptance and retirement decisions. The labor supply states at the individual level are: full-time employment (FT); non-employment (NE); and, for women only, part-time employment (PT). Combining across spouses, there are a total of 12 labor supply and retirement states for couple households. An individual permanently exits the labor force when he or she enters retirement (RT).

We describe below: the life-cycle optimization problem (Section 2.3); the wage process (Section 2.4); and the empirical specification of preferences (Section 2.5). Finally, we characterize optimal search, employment, retirement and consumption behavior (Section 2.6). In Appendix C we describe the exogenous processes that determine household type and fertility outcomes.

2.2 Notational Definitions

Individuals are indexed by n. Age, measured in quarters of a year, is denoted by t. The individual's household type at age t is denoted by $H(n,t)$ where $H(n,t) \in$

[3] We do not distinguish cohabitation from marriage. Henceforth, we refer to the adult members of couple households as "spouses".

[4] The timing of the transition from education into the labor force is assumed to be exogenous.

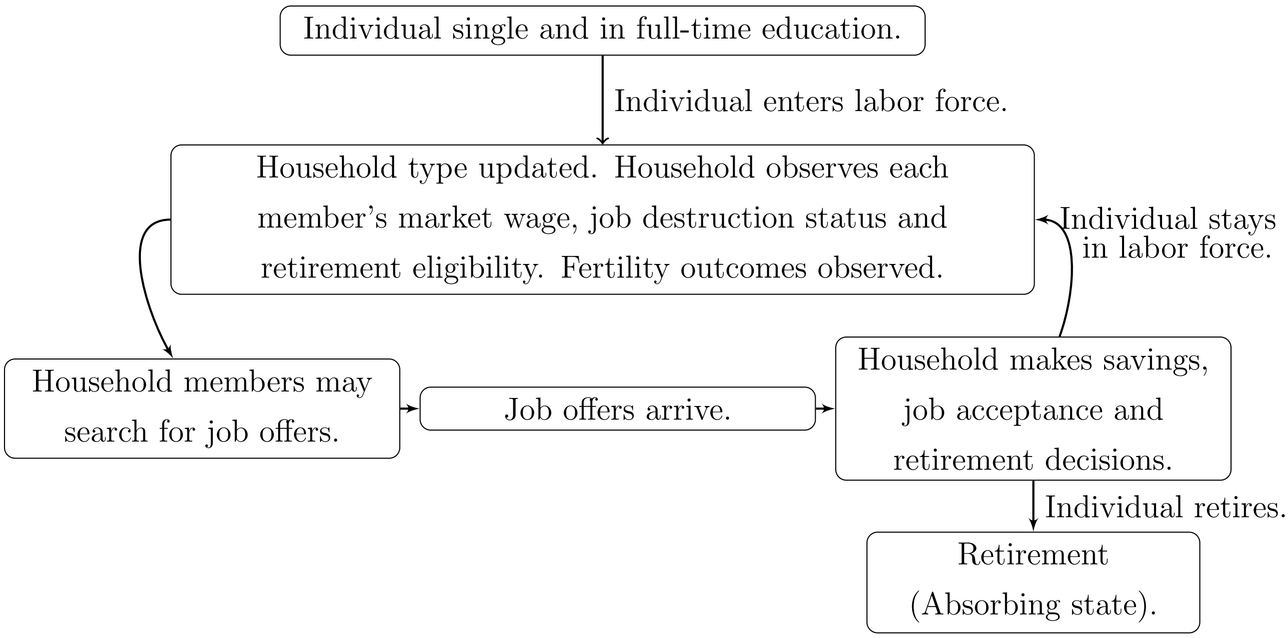


Figure 1: Timing of events over the life-cycle.

{Single-adult Household, Couple household}. We use $i(n,t)$ and $j(n,t)$ to denote the indexes of the female and male members of individual n's age-t household; we abbreviate to i and j when referring to women and men in situations where the nature of the household is not relevant. Reflecting the empirical implementation, this notation allows an individual to switch back and forth between being single and cohabiting, and to cohabit with different spouses at different points in the life-cycle.

2.3 Life-cycle Optimization Problem

Similar to Blundell *et al.* (2012), we adopt a unitary model in which household savings decisions and the search, labor supply and retirement decisions of the household members are made to maximize discounted expected future household utility.[5,6] All individuals must retire at or before age 65, and we model household choices prior to the time when the youngest household member is age 65. Individual n's age-t household seeks to maximize:

$$E_t \left[\sum_{\tau=t}^{\overline{T}_n - 1} \delta^{t-\tau} u^{H(n,\tau)}(m_{n,\tau}, D_{n,\tau}, S_{n,\tau}) + \delta^{T_n - \tau} \overline{V} \right], \tag{1}$$

where δ is the subjective time discount factor, $\overline{T}_n$ is the time when the youngest member of n's household is age 65, $u^{H(n,t)}(m_{n,t}, D_{n,t}, S_{n,t})$ denotes the household's flow utility function, and $\overline{V}$ denotes the terminal value. The utility function is defined over household consumption, $m_{n,t}$, the labor supply and retirement statuses of the adult household members, $D_{n,t}$, and the search intensities of the household members, $S_{n,t}$. The terminal value is given by:

$$V^T = B(n, H(n,\tau)) u^{H(n,\tau)}(m_{n,\overline{T}_n}, D_{n,\overline{T}_n}, S_{n,\overline{T}_n}). \tag{2}$$

At time $\overline{T}_n$ onward all household members are retired and therefore search intensities are zero. The household consumes each period its pension income plus the actuarially fair annuity value of any accumulated assets. $B(n, H(n,\tau))$ is the discounted average duration of the retirement periods of the household members.[7]

We assume rational expectations with respect to the future realizations of wages, job destructions, job arrivals, retirement eligibility and children. However, while marriages and divorces occur exogenously at the rates dictated by the household formation process, we impose that cohabiting individuals make decisions assuming that divorce will not occur, and single individuals make decisions assuming zero probability of future marriage. The latter assumption allows us to proceed without the need to specify expectations about

[5]The unitary approach avoids difficult issues surrounding the identification of dynamic decision processes within the household that arise in a collective setting. Eckstein and Lifshitz (2011) and Eckstein and Lifshitz (2012) discuss the life-cycle labor supply behavior of couples under various assumptions on the intra-household decision process.

[6]In general, the joint modeling of spouses' behavior is absent in dynamic structural life-cycle models of labor supply and savings. Typically, the analysis either focuses on single individuals or specifies an exogenous process for the earnings of any other household members (see, e.g., Frederick, 2005, Low, 2005, Attanasio *et al.*, 2008, Heathcote *et al.*, 2009, Low *et al.*, 2010, and Haan and Prowse, Forthcoming). In terms of the nature of the choice set, our model is similar to van der Klaauw and Wolpin (2008), who incorporate the life-cycle labor supply of single individuals and married couples, along with household saving. In contrast to our work, van der Klaauw and Wolpin (2008) focus on the retirement decision, and do not consider public insurance, beyond Social Security benefits for retirement.

[7]The empirical implementation includes different life expectancies for men and women. See 3 for further details.

the characteristics of the future spouses.[8] Although the imposed marriage and divorce expectations diverge from their objective counterparts, the implication of this assumption for behavior are relatively minor. Specifically, optimal behavior is likely to vary little with the probability attached to future marriage and divorce as: (i) there is a great deal of persistence in household type; (ii) behavior is in part driven by precautionary motives to save and secure employment to self-insure in the near future, and these incentives are little affected by the possibility of a change in household type at some, likely more distant, time in the future; and (iii) irrespective of household type there exist incentives to accumulate wealth and entitlement to public transfers. See Attanasio *et al.* (2008) for further discussion.

Consumption decisions are subject to the intertemporal budget constraint and a non-negativity constraint on household wealth (see Section 2.3.1). As described in Section 2.3.2, the intertemporal budget is also the channel through which public insurance programs, including Unemployment Insurance and universal Welfare, enter the model. Labor supply and retirement decisions may be constrained by labor market frictions (see Section 2.3.3) and by eligibility restrictions on access to retirement (see Section 2.3.4).

2.3.1 Intertemporal Budget Constraint

With no change in household type at age t, the intertemporal budget constraint for individual n's household is given by:

$$A_{n,t} = A_{n,t-1}(1 + r) + y_{n,t} - m_{n,t}, \tag{3}$$

In the above, $A_{n,t}$ denotes the combined net value of the household's financial, housing and tangible assets, r is the real interest rate, and $y_{n,t}$ is the net-of-tax real value of the household's income from employment and social transfers. Marriage augments the assets of person n's household by the assets of the new spouse. In the event of divorce, household assets are assumed to be divided equally between the spouses.

Households are assumed to be unable to borrow against future earnings or future entitlements to social transfers. Reflecting this, household assets must be non-negative:

$$A_{n,t} \geq 0. \tag{4}$$

Given this borrowing constraint, there is a rationale for public insurance to allow households to smooth the marginal utility of consumption over the life-cycle in the presence of employment and productivity shocks.[9]

[8] Expectations about the nature of any future spouse are complex as potential future spouses vary along many dimensions including by demographic traits (education, children), latent taste shifters, and state variables such as accumulated experience and assets.

[9] Given heterogenous households, social transfers may be desirable as well on redistributive grounds.

The empirical implementation will focus on Germany. Our model of the net-of-tax real value of household income is based closely on the German legislation pertaining to the tax and transfer system. In this system, Welfare benefits and Unemployment Insurance provide the major share of income to non-working households before entering retirement. Suppose that individual n is cohabiting and his or her age-t household comprises woman $i(n,t)$ and man $j(n,t)$. The net-of-tax real value of household income is given by:

$$\begin{aligned} y_{n,t} &= \left(W_{i(n,t),t}h_{i(n,t),t} + \mathrm{UI}_{i(n,t),t} + \mathrm{Pension}_{i(n,t),t} - \mathrm{SSC}_{i(n,t),t}\right) + \\ &\quad \left(W_{j(n,t),t}h_{j(n,t),t} + \mathrm{UI}_{j(n,t),t} + \mathrm{Pension}_{j(n,t),t} - \mathrm{SSC}_{j(n,t),t}\right) + \\ &\quad \mathrm{WE}_{n,t} - \mathrm{Tax}_{n,t} - \mathrm{K}_{n,t}. \end{aligned} \tag{5}$$

In the above, h denotes hours. "UI" denotes Unemployment Insurance benefits, "SSC" denotes Social Security Contributions, and "Pension" denotes public pension benefits; all three schemes are administered at the individual level. "WE" and "Tax" denote Welfare benefits and Income tax respectively; both programs are administered at the household level. "K" denotes the cost for children, and includes child benefits and child-care costs. Net income for a single adult household is obtained by taking (5) and suppressing the earnings, Unemployment Insurance, Pension, and Social Security contributions of person with the opposite gender. Children are assumed to reside in the mother's household. Child benefits and child-care costs therefore do not enter a single man's budget constraint.

Our analysis of interactions between public and intra-households insurance focuses on two key components of the public insurance system: Unemployment Insurance and Welfare benefits. These two institutions are described below in Section 2.3.2. The remaining institutional components of the budget constraint, that is Income tax, Social Security Contributions, pension benefits, child benefits and child-care costs, are described in Appendix B.

2.3.2 Unemployment Insurance and Welfare Benefits

A non-employed individual living in Germany receives Welfare benefits (Social Assistance) or Unemployment Insurance, or some combination thereof. Unemployment Insurance provides eligible non-employed individuals with benefits worth 60% of previous net earnings (a higher replacement rate of 67% applies if the individual has one or more dependent children). Unemployment Insurance benefits are capped at around 1750 Euros per month. Unemployment Insurance benefits are paid for an entitlement period that depends on the recipient's recent working history and his or her age at the start of the non-employment spell. Specifically, individuals accumulate one month of entitlement to Unemployment Insurance for every two months of employment, up to an age-specific *maximum entitlement* *period.*[10]

The maximum entitlement period is increasing in age has varied over time during our sample period. Specifically, in 1997 the maximum entitlement period was reduced for those aged 42 - 46, 49 - 52 and 54 - 56 years at the point of entering non-employment. For all other age groups, the maximum entitlement period did not change during the sample period.[11]

In our model we capture the variation in incentives induced by the reduction of the maximum entitlement period in 1997 by working with separate models of the tax and transfer system for the periods 1991 - 1996 and 1997 - 2005. The maximum entitlement period for Unemployment Insurance in each period follows the rules described in Table 1. For the 1991-1996 period we use the year 1995 tax and universal Welfare rules, and for the 1997-2005 period we use the year 2000 rules.

Age at start of non-employment spell	Date at start of non-employment spell	
	January 1991 - March 1997	April 1997 - December 2005
$<$ 42 years	12	12
42-43 years	18	12
44 years	22	12
45-46 years	22	18
47-48 years	22	22
49-52 years	26	22
53 years	26	26
54-56 years	32	26
$\geq$ 57 years	32	32

Notes: The actual Unemployment Insurance entitlement period is determined by the the individual's employment history.

Table 1: Age-specific maximum Unemployment Insurance entitlement period (months).

Unemployment Insurance benefits are not means tested, i.e., benefits are neither contingent on the earnings of other household members nor linked to the household's income

[10]In principle, those who voluntarily choose to move into non-employment must wait three months before starting to receive Unemployment Insurance benefits. We neglect this rule because, in reality, very few entitled individuals are prevented from claiming Unemployment Insurance immediately upon becoming non-employed. Specifically, according to the administrative data of the "Bundesagentur fuer Arbeit" (German Federal Employment Agency) during the period 1996 - 2005 about 5% of those making a transition from employment into non-employment are sanctioned (see Bundesagentur fuer Arbeit (2013)).

[11]In 2006 there was another reform that further reduced the maximum entitlement period for individuals in particular age categories. This reform occurred after the end date of our sample and, therefore, does not feature in our analysis.

from asset holding.[12] Further, there is no wealth test. Unemployment Insurance benefits are not directly taxed. Instead, the household's average tax rate is based on taxable earnings, taxable investment income and any income from Unemployment Insurance benefits. The household's tax liability is then determined by applying the average tax rate to the household's taxable earnings and investment income. When entitlement to Unemployment Insurance is exhausted, Unemployment Insurance-eligible individuals may instead receive Unemployment Benefits, paid at a lower rate of 53% (57% with dependent children) of previous net earnings. Unemployment Benefits continue indefinitely. However, unlike Unemployment Insurance, Unemployment Benefits are means-tested against the earnings of the spouse, and there is a wealth test in line with the rules for Welfare benefits.

Welfare benefits are designed to ensure that a household income does not fall short of threshold determined by household composition and housing costs.[13] In contrast to Unemployment Insurance, Welfare benefits are means-tested against the taxable earnings and Unemployment Insurance benefits of all household members. The withdrawal rate against Unemployment Insurance benefits is 100%, and the withdrawal rate with individual earnings is close to 100%.[14] Welfare benefits are paid only to households that satisfy a wealth test.[15] Finally, welfare benefits do not have tax implications.

2.3.3 Labor Market Frictions

Individuals are subject to employment risk that arises from the combination of exogenous job destructions and search frictions. Regarding job destructions, each period an employed individual experiences a job destruction with a probability that depends on the individual's gender, age and education. An individual who experiences a job destruction cannot work in the current period; the individual must enter non-employment or, if eligible, may retire. We estimate gender, age and education specific the job destruction probabilities prior to estimation of the parameters of the life-cycle model. Appendix A provides further details. An employed individual who is not subject to a job destruction may remain in employment.

A non-employed individual may move into employment only if he or she receives a

[12] Recipients are allowed to work up to 15 hours per week while claiming Unemployment Insurance. However, benefits are withdrawn at a rate close to 100%.

[13] For a single adult household, the maximum value of universal Welfare (including housing benefits) is around 600 Euros per month, assuming average housing costs. The value increases with numbers of adults and children in the household, and varies to reflect local housing costs.

[14] Approximately 140 Euros per month of taxable earnings are exempt from means-testing.

[15] In particular, households with assets above an threshold of around 10000 Euros do not qualify for universal Welfare. The wealth test threshold has varied slightly over time and is slightly more generous for older individuals.

job offer. Job offers are obtained via costly job search and at most one offer is received each period. Given individual search intensity $s_{n,t} \in [0, 1/\omega^M_{n,t}]$, a non-employed individual receives a job offer with probability:

$$P_{Job\ offer}(s_{n,t}) = s_{n,t}\omega_{n,t}. \tag{6}$$

The search productivity parameter, $\omega_{n,t} > 0$, reflect both households' search technologies and firms' preferences. Motivated by the observed heterogeneity in the transition rate into employment, the empirical specification allows the value of the search productivity parameter to vary by age and household type.

A man's job offer is for a full-time job. A woman's job offer specifies either full-time or part-time work; the probability of a job offer being for part-time work is ξ^F. Women have constrained flexibility to adjust labor supply on the intensive margin: each period a full-time working woman may move to part-time employment with probability o_{FT-PT}, and a woman in part-time employment has the option of making a transition into full-time employment with probability o_{PT-FT}. The probabilities ξ^F, o_{FT-PT} and o_{PT-FT} are estimated within the structural model and are allowed to vary by household type.

2.3.4 Eligibility for Retirement

The compulsory retirement age is 65 years[16]. However, if eligible, an individual may choose to take early retirement. In reality, a complex set of rules determine an individual's eligibility for early retirement. We approximate these rules and specify that each period a retirement-ineligible individual aged 40 or older becomes eligible for early retirement with a probability that varies freely by gender and household type. Once eligible for early retirement, the individual maintains this status. The retirement eligibility parameters are estimated jointly with other parameters of the life-cycle model.

2.4 Wage Process

We posit an individual-level process for the market wage, i.e., the wage that is observed prior to search intensity being chosen and the wage that determines earnings should the individual be employed. Following, e.g., Low *et al.* (2010), sample wage observations are assumed to additionally contain measurement error. Note, we model the wage process jointly with labor supply and retirement behavior; in doing so, we explicitly account for the effect of wage-based selection into employment on the distributions of accepted wages.

[16]In principle, it is possible to delay retirement beyond the compulsory retirement age. However, empirically, very few individuals choose to work beyond this age. In a life-cycle model of retirement, Haan and Prowse (Forthcoming) show that estimates of key preference parameters and responses to pension reforms do not depend strongly on whether individuals are allowed to work beyond the compulsory retirement age.

2.4.1 Market Wages

The age t log real market wage of individual n is given by:

$$\begin{aligned}\log W_{n,t} \;=\; & \beta_1^F \times Female_n + \beta_1^M \times Male_n + \beta_2^F Education_{i,t}^F \times Female_n + \beta_2^M Education_{n,t} \times Male_n + \\ & \beta_3^F Human\ Capital_{n,t}^F \times Female_n + \beta_3^M Human\ Capital_{n,t}^M \times Male_n + \kappa_{n,t}. \qquad (7)\end{aligned}$$

In the above, "*Education*" refers years of education at the time of labor market entry and $\kappa_{n,t}$ represents accumulated wage shocks.

Human capital is zero when the individual transitions from education into the labor force. Subsequent to labor market entry, human capital is augmented by employment, as in Eckstein and Wolpin (1989). In the spirit of Mincer and Polachek (1974) and, more recently, Adda *et al.* (2011), human capital atrophies during spells of unemployment. Specifically, human capital evolves according to:

$$Human\ Capital_{n,t} = \begin{cases} Human\ Capital_{n,t-1} + 0.25 \\ \qquad \text{if } \; n \; \text{ employed at age } \; t-1,^{17} \\ Human\ Capital_{n,t-1} \times (\beta^F_{Atrophy} \times Female_n + \beta^M_{Atrophy} \times Male_n) \\ \qquad \text{if } \; n \; \text{ non-employed at age } \; t-1. \end{cases} \qquad (8)$$

In the above, $\beta^F_{Atrophy} \in [0,1]$ and $\beta^M_{Atrophy} \in [0,1]$ control the atrophy rate of the woman's and men's human capital during spells of non-employment.[18]

Wage shocks, which we refer to as productivity risk, are assumed to be permanent. The unobserved component of the market wage therefore follows a unit root process:

$$\kappa_{n,t} \;=\; \kappa_{n,t-1} + \zeta_{n,t}. \qquad (9)$$

The permanent shock, ζ, is assumed to be independent over time and households, and independent of the previous realizations of all other variables. Further, we assume $\zeta_{n,t} \sim N(0, \sigma^2_{\zeta,F})$ for women and $\zeta_{n,t} \sim N(0, \sigma^2_{\zeta,M})$ for men. For couples, the correlation coefficient ρ_ζ describes the intra-household correlation of the permanent wage shocks.

Note, the all parameters of the wage process are allowed to vary by gender. This aspect of the specification captures gender differences in labor market conditions labor market-related behaviors. For example, a difference in the variances of the permanent wage shocks by gender may result from gender differences risk taking, competitiveness or occupational choice, among other mechanisms.

Our specification of the wage shocks for individuals in single-adult households is similar to that adopted by Low (2005) and Heathcote *et al.* (2009) when modeling single-agent

[17] Recall, one period last a quarter of a year.

[18] As modeled, those with high human capital suffer more skill depreciation during a period of unemployment than those with low human capital. This specification is consistent with the empirical results of Adda *et al.* (2011).

labor supply. Previous studies that have used similar specifications of persistent unobservables in models of spouses wages include Attanasio *et al.* (2008) and Blundell *et al.* (2012). Between-spouse correlations in permanent wage shocks may result from intra-household insurance agreements or joint decisions regarding job or occupational choice. We assume no market for insurance against permanent wage shocks. Further, we assume that the household has no information, beyond that given above, about the values of future permanent wage shocks.[19]

2.4.2 Measurement Error

Sample wage observations, $\widetilde{W}_{n,t}$, are assumed to contain measurement error of the following form:

$$\log \widetilde{W}_{n,t} = \log W_{n,t} + \nu_{n,t}, \tag{10}$$

where $\nu^F_{n,t}$ is assumed to occur independently over time and households with $\nu_{n,t} \sim N(0, \sigma^2_{\nu,F})$ for women and $\nu^M_{j,t} \sim N(0, \sigma^2_{\nu,M})$ for men. Measurement error is further assumed to occur independently of all other variables. For couples, the correlation coefficient ρ_ν describes the intra-household correlation of measurement error in wages.

2.5 Empirical Specification of Preferences

Recall, household preferences are defined over household consumption, and each household member's labor supply and retirement status and search intensity. Given the focus of this paper on interactions between private insurance from labor supply and public insurance from transfers, we follow Low (2005) and Attanasio *et al.* (2008) and allow complementarity or substitutability between consumption and leisure. For couple households, we additionally allow non-separability between the spouses' leisure times.[20]

2.5.1 Single-adult Households

Suppose that individual n is single at age t. The household utility function is given by:[21]

$$u^{\text{Single-adult}}(m_{n,t}, D_{n,t}, S_{n,t}) = \frac{\left(\eta(D_{n,t}) m_{n,t}/e_{n,t}\right)^{1-\rho_n}}{1-\rho_n} - \frac{1}{2} s^2_{n,t}. \tag{11}$$

In 11, ρ_n is the coefficient of relative risk aversion. This parameter takes the value ρ^F for female-headed single-adult households and ρ^M for male-headed single-adult households.

[19]Blundell *et al.* (2012) find little evidence of anticipation of wage shocks; for further discussion see Blundell and Preston (1998), Pistaferri (2001, 2003) and Guvenen (2007).

[20]See also Browning and Meghir (1991) and Blundell *et al.* (2012).

[21]For a single-adult household, the search intensities of the household members, $S_{n,t}$, corresponds to the individual's search intensity, $s_{n,t}$.

Household consumption has been divided by the number of adult equivalents in the household, $e_{n,t}$.[22] The disutility of search is increasing and convex in the intensity of search, $s_{n,t}$ (see Section 2.3.3 for discussion of the search technology).

The household's taste for consumption, $\eta(D_{n,t})$, is allowed to vary with the household member's labor supply and retirement status and with interactions between labor supply and retirement status and observables, $v_{n,t}$ (age and, for women, children) and a permanent unobservable, μ_n^F.[23] For female-headed households we specify:

$$\ln \eta(D_{n,t} = p) \;=\; \gamma_{I,p}^F + \gamma_{v,p}^F v_{n,t}^F + \gamma_{\mu,p}^F \mu_n \text{ for } p = FT, PT, NE, RT, \tag{12}$$

and for male-headed households:

$$\ln \eta(D_{n,t} = q) \;=\; \gamma_{I,q}^M + \gamma_{v,q}^M v_{n,t}^M + \gamma_{\mu,q}^M \mu_n \text{ for } q = FT, NE, RT. \tag{13}$$

The permanent unobserved preference shifter, μ_n, is assumed to be assigned to the individual at the time of his or transition from eduction into the labor force. Values of μ_n are assumed to be assigned independently over individuals and independent of education and gender. Further, each value of μ_n is a draw from a standard normal distribution. The individual maintains his or her assigned value of μ_n through marriages and divorces. μ_n therefore impacts on the individual's labor supply preferences over the entire life-cycle.

2.5.2 Couple Households

Suppose that individual n is cohabiting at age t and that the household comprises woman $i(n,t)$ and man $j(n,t)$. The household flow utility function is given by:

$$u^{\text{Couple}}(m_{n,t}, D_{n,t}, S_{n,t}) = \frac{\left(\eta^C(D_{n,t}) m_{n,t}/e_{n,t}\right)^{1-\rho^C}}{1-\rho^C} - \frac{1}{2}\left(s_{i(n,t),t}^2 + s_{j(n,t),t}^2\right), \tag{14}$$

where ρ^C is the coefficient of relative risk aversion for a couple household, $s_{i(n,t),t}$ and $s_{j(n,t),t}$ denote the female and male spouses' search intensities, and $e_{n,t}$ is the number of adult equivalents in the household. A couple household's taste for consumption, $\eta^C(D_{n,t})$, is allowed to vary with the labor supply and retirement status of the household members.

[22] We use the OECD-modified equivalence scale (Hagenaars *et al.*, 1996). Accordingly, the first adult receives a weight of 1, each subsequent adult and each child aged 14 and over receives a weight of 0.5, and each child aged under 14 receives a weight of 0.3.

[23] In the estimation, we do not allow for different effects of the observables or the permanent unobservable on the woman's preference for non-employment and retirement, i.e., we impose $\gamma_{\mu,UN}^g = \gamma_{\mu,RT}^g$ and $\gamma_{v,UN}^g = \gamma_{v,RT}^g$ for $g = F, M$. Instead, we capture the age profile of transitions into retirement by modeling the persistent and age-varying restrictions on access to retirement (see Section 2.3.4). For identification purposes, we normalize the preference parameters associated with non-employment to zero, i.e., we impose $\gamma_{I,UN}^g = \gamma_{\mu,UN}^g = \gamma_{v,UN}^g = 0$ for $g = F, M$.

Further, we allow the effect of the woman's labor supply and retirement status on the household's taste for consumption to vary with: her observable characteristics, $\upsilon_{i(n,t),t}$ (children and her age); her permanent unobserved preference shifter, $\mu_{i(n,t)}$; and her spouse's permanent unobservable, $\mu_{j(n,t)}$. The same interactions are allowed between the man's labor supply and retirement status, his observable characteristics and the spouses' permanent unobserved preference shifters.[24]

Formally, let $d_{i(n,t),t}$ and $d_{j(n,t),t}$ denote the labor supply and retirement statuses of the female and male spouses respectively. For $p = FT, PT, NE, RT$ and $q = FT, NE, RT$ we specify:

$$\begin{aligned} \ln \eta^C(d_{i(n,t),t} = p, d_{j(n,t),t} = q) = \gamma^C_{I,p,q} \quad &+ \quad \gamma^{C,F}_{v,p} \upsilon_{i(n,t),t} + \gamma^{C,F}_{\mu,p}[\mu_{i(n,t)}, \mu_{j(n,t)}] \\ &+ \quad \gamma^{C,M}_{v,q} \upsilon_{j(n,t),t} + \gamma^{C,M}_{\mu,q}[\mu_{i(n,t)}, \mu_{j(n,t)}]. \end{aligned} \quad (15)$$

2.6 Optimal Life-cycle Behavior

Each period, the household's optimization problem proceeds in two stages: optimization of search followed by optimization of consumption, labor supply and retirement behavior. At the search stage, the household observes each member's market wage, job destruction status and retirement eligibility, and fertility outcomes are observed by the household. Conditional on this information, the household determines each adult's optimal search intensity. Job offers may then arrive. The set of labor supply and retirement states available to the household is denoted by $g \in G$. At the second stage, household consumption and each individual's labor supply and retirement status are optimized, subject to the intertemporal budget constraint and the non-negativity constraint on household wealth and given the set of feasible labor supply and retirement states, g.

We use household type-specific value functions to characterize optimal life-cycle behavior. Consider individual n who resides in a household of type $H(n,t)$ at age t. Let $Z_{n,t}$ denote the productivity shocks that hit the household members when the individual n is age t (see Section 2.4). Further, let $Q_{n,t}$ denote all remaining state variables for individual n's age-t household. The state variables $Q_{n,t}$ are measured after age-t job destructions have been realized but before age-t job search occurs.[25] Define $t' \equiv t + 1$. The value

[24] For the purpose of estimation, we impose additional restrictions on couples' preferences. These mirror the restrictions imposed on the preferences of single-adult households (see footnote 23).

[25] $Q_{j,t}$ consists of the following variables for each household member: the unobserved preference shifter, μ, current job destruction status, experience, human capital, Unemployment Insurance entitlement period, and accumulated permanent wage shocks. The state space further includes: household assets; the ages of any children; and the current parameters of the tax and public insurance systems.

function for individual n's age-t household is:

$$V_t^{H(n,t)}(Q_{n,t}, Z_{n,t}) =$$
$$\max_S \left\{ \sum_{g\in G} P(g|S) \max_{D\in g,m} \left\{ u^{H(n,t)}(m, D, S) + \delta E[V_{t'}^{H(n,t)}(Q_{n,t'}, Z_{n,t'})|m, D, Q_{n,t}, Z_{n,t}] \right\} \right\}. \tag{16}$$

The expectation in (16) is with respect to $Q_{j,t'}$ and $Z_{j,t'}$. $P(g|S)$ denotes the probability of set g of employment and retirement options being available given that the household members search with the intensities listed in S. Optimal household search maximizes the expression in the outer braces of (16). Given a realized set of labor supply and retirement options, the household's optimal consumption, labor supply and retirement choices household maximize the expression in the inner braces of (16).

3 Data and Sample

We use survey panel data from the SOEP from the years 1992 – 2006 (see Wagner *et al.*, 2007, for a description of the SOEP). These surveys provide retrospective information covering the calender years 1991 – 2005. We construct a panel sample of single-adult and couple households in which households are observed at quarterly intervals. The sample is restricted to single-adult households in which the adult household member is aged 16–65 years and couple households in which both household members are aged 16 or older and at least one adult household member is age 65 or younger. The sample is further restricted to households in which both household members have completed full-time education. Last, we exclude households in which any adult household member ever reports that he or she is self-employed or works for the Civil Service. The estimation sample contains X individual-quarter observations (corresponding to X household-quarter observations). Around 70% of the household observations are of couples. Table 4 in Appendix D contains descriptive statistics, and the accompanying text provides further information about the sample construction.

In addition to the SOEP data we make use of the Human Mortality Database for Germany (HMD)[26] to construct gender specific life expectancies which affect the terminal value of the value function, see Section 2.3. Specifically the life tables in the HMD include survival probabilities and life expectancies that vary by age and birth cohort. Based on this information we construct the remaining life-expectancy at the age of 65 years for men an women.

[26]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.

4 Indirect Inference Estimation Routine

4.1 Overview

Estimates of the structural parameters are obtained using indirect inference (see Smith, 1993, Gourieroux *et al.*, 1993, and Gallant and Tauchen, 1996).[27] This simulation-based estimation method uses an auxiliary model to summarize both the observed estimation sample and a sample simulated using the decision rules and other equations of motion specified by the structural model. Values of the structural parameters are chosen to maximize the similarity between the observed sample and the simulated sample, as viewed from the perspective of the auxiliary model.

The auxiliary model need not be correct; however, the auxiliary model must contain sufficient information to ensure identification of the structural parameters, and efficiency is improving in the auxiliary model's accuracy.[28] Our auxiliary model consists of J sub-models with sub-model parameters ϕ_j for $j = 1, ..., J$. Sub-model j specifies the conditional density of one of the three modeled outcome variables: accepted wages; employment and retirement outcomes; or household assets.[29] Section 4.2 provides a description of the auxiliary model.

Following, e.g., Gourieroux *et al.* (1993), van der Klaauw and Wolpin (2008) and Tartari (2008), we use an Indirect Inference estimation routine based on the score function of the auxiliary model. Alternative implementations of indirect inference entail either matching estimated auxiliary parameters or maximizing the quasi likelihood specified by the auxiliary model.[30] As noted by Gallant and Tauchen (1996), relative to these alternatives, Indirect Inference based on the score function has the computational advantage of not requiring the auxiliary model parameters be estimated at each function evaluation.

Let y^o and $y^s(\phi)$ denote the observations in, respectively, the observed estimation sample and a sample simulated from the structural model with parameter values ϕ. Further, let $\widehat{\psi}_j$ denote the maximum likelihood estimate of the parameters of the j^{th} sub-model

[27]Conventional Maximum Likelihood Estimation is not feasible here due to the combination of multiple sources of unobserved heterogeneity, endogenous initial conditions, missing values, and discrete and continuous outcome variables.

[28]Indirect Inference with a correctly-specific auxiliary model and appropriately-chosen weighting matrix is asymptotically equivalent to Maximum Likelihood (Gourieroux *et al.*, 1993).

[29]For discrete outcomes, such as employment status, the auxiliary sub-model specifies instead a conditional probability mass function.

[30]In related life-cycle models, Low and Pistaferri (2010), Adda *et al.* (2011) and Haan and Prowse (Forthcoming) use Indirect inference based on matching auxiliary model parameters. Altonji *et al.* (Forthcoming) conduct indirect inference based on the quasi likelihood given by the auxiliary model. De Nardi *et al.* (2010) and Eckstein and Lifshitz (2011) use the closely-related Method of Simulated Moments.

obtained using the estimation sample. By definition $\left.\frac{\partial l_j(\psi_j;y^o)}{\partial\psi_j}\right|_{\psi_j=\widehat{\psi}_j}=0$, where $l_j(\psi_j;y^o)$ denotes the log likelihood for the estimation sample observations as implied by the j^{th} sub-model. Values of the structural parameters are chosen to minimize a quadratic loss function formed from the auxiliary model scores, evaluated on the simulated sample and at auxiliary model parameter values $\widehat{\psi}_j$ for $j=1,...J$. Formally, our Indirect Inference estimator of the structural parameters is defined by:

$$\widehat{\phi}=\arg\min_{\phi}\left.\frac{\partial l(\psi;y^s(\phi))}{\partial\psi'}\right|_{\psi=\widehat{\psi}}\Sigma\left.\frac{\partial l(\psi;y^s(\phi))}{\partial\psi}\right|_{\psi=\widehat{\psi}}, \tag{17}$$

where Σ is a positive semi-definite weighting matrix, ψ is a vector that contains all sub-model parameters, and $\frac{\partial l(\psi;y^s(\phi))}{\partial\psi}$ denotes the stacked scores of the auxiliary sub-model log likelihoods for the observations in the simulated sample. The weighting matrix, Σ, is a block diagonal matrix formed from the inverse Hessians of each of the auxiliary sub-models, evaluated on the observed estimation sample and at the maximum likelihood estimates of the auxiliary model parameters. The optimization process uses a parallel version of the implementation of the simulated annealing algorithm introduced by Corana *et al.* (1987) and discussed in Goffe *et al.* (1994). We obtain standard error using the formula provided by Gourieroux *et al.* (1993).

4.2 Auxiliary Model

The auxiliary model contains a total of 310 parameters, and is designed to provide identifying information on the 84 parameters of the structural model. We describe below the auxiliary sub-models of: (i) sample wage observations; (ii) employment and retirement outcomes; and (iii) household assets. The discussion links the specification of the auxiliary model to identification of the structural parameters.[31]

4.2.1 Auxiliary Sub-models of Sample Wage Observations

We specify the following auxiliary sub-model of sample log wage observations:

$$\log\widetilde{W}_{n,t}\sim N\left(x^w_{n,t}b^w,c^2_{n,t}\right). \tag{18}$$

The nature of observable characteristics $x^w_{n,t}$ is discussed below. The conditional variance $c^2_{n,t}$ of the log sample wage observations depends on age as follows:

$$\log c_{n,t}=c_1+c_2Male_n+c_3Age_{n,t}+c_4Age_{n,t}Male_n, \tag{19}$$

[31] As noted by, e.g., Adda *et al.* (2011), estimates of the auxiliary model parameters, obtained using either the estimation sample or the simulated sample, might be inconsistent because employment, retirement and savings decisions are endogenous and wages are sampled only for employed individuals. However, the structural model accounts explicitly for these endogenous choices and for selectivity in observed wages. Estimation therefore delivers consistent estimates of the structural parameters.

where $Male_n$ is a male indicator. Conditional on the observables, $x^w_{n,t}$, the auxiliary sub-model stipulates that sample wage observations are independent over time and individuals.

Three features of the auxiliary sub-model of sample wage observations are important for identification. First, $x^w_{n,t}$ contains an intercept, a male indicator, years of education, years of experience and interactions of latter two variables with the male indicator. The corresponding coefficients provide identifying information about the gender-specific intercepts and gender-specific coefficients on education and human capital in the market wage equation. Second, $x^w_{n,t}$ includes the fraction of the individual's post-education life prior to age t if he or she have been unemployed, and the interaction of this life-cycle unemployment rate with the male indicator. The relationship between the sample wage observations and the life-cycle unemployment rate speaks to the extent of human capital atrophy during unemployment spells, and thus provides identifying information about the gender-specific human capital atrophy rates. Third, the non-age-dependent components of the variance are informative about the extent of measurement error in men's and women's wages. Meanwhile, the age-dependent components of the variance relate to the variance of the permanent shocks to men's and women's wages.

To ensure that the auxiliary model contains identifying information about the cross-spouse correlations of the permanent wage shocks and measurement errors we supplement the above model of log wages with the following two models of wage changes:

$$\log \widetilde{W}_{n,t} - \log \widetilde{W}_{n,t-k} \sim N\left(x^{\Delta(k)}_{n,t} b^{\Delta(k)}, c^2_{\Delta(k)}\right) \quad \text{for} \quad k = 1, 2. \tag{20}$$

The two wage change models are estimated using only couple household in which wages are observed for both spouses in period t and k years previously. The dependent variables pertains to the randomly chosen reference household member (see Section E). In $x^{\Delta(k)}$ we include an intercept, male indicator and the change in the spouse's log wage between the current period and k years previously. The cross-spouse correlations in wage changes is driven by both the correlation in the permanent wage shocks and the correlation in the measurement errors. However, permanent wage shocks become more important in driving the cross-spouse correlation in wage changes as the time horizon over which the wage change is measured increases. Thus, by modeling the cross-spouse correlation in wage changes over one and two year intervals we are able to identify the between-spouse correlations in the permanent wage shocks and the measurement errors.

According to the structural model, selection into employment based on the market wage leads mechanically to a difference between the distributions of accepted and market wages. The estimation procedure recognizes this important aspect of the data generation process. Specifically, when working with the simulated sample, we include only simulated wage observations that have survived the same employment-based selection process as the wage observations that appear in the estimation sample.[32]

4.2.2 Auxiliary Sub-models of Employment and Retirement Outcomes

The auxiliary sub-models of employment and retirement outcomes consist of: multinomial logit models for employment and retirement outcomes at the individual level; and a multinomial logit model of the joint employment and retirement outcomes of cohabiting individuals.

For the individual-level models, we estimate 5 multinomial logit models for women, and 4 multinomial logit models for men. When estimating the models, and when evaluating the score functions, we pool observations over quarters and use single and cohabiting individuals. For women, the models describe the probabilities of being in unemployment, part-time employment, full-time employment and retirement, while for men, part-time work is omitted. All models condition on age variables. We list below further explanatory variables included in each model.

1. (Men and women) Own previous employment status; own previous employment status interacted with age variables; previous employment status of spouse, if cohabiting.

2. (Men and women) Own previous wage; previous wage of spouse, if cohabiting.

3. (Men and women) Own education; education of spouse, if cohabiting.

4. (Men and women) Fraction of own post-education life in unemployment; fraction of spouse's post-education life in unemployment, if cohabiting.

5. (Women only) Age category of youngest child.

All coefficients are allowed to vary according to whether the individual is single or cohabiting. Conditional on observables, observations are assumed to be independent over time and individuals.

Model 1 speaks to the rates of transition from unemployment to full-time and, for women, from unemployment to part-time employment. This model is informative about the productivity with which individuals search for full-time and part-time jobs, and the variation in search productivity according to age. Model 1 also summarizes the rate of

[32]There are two further reasons for missing wages observations in the estimation sample. First, due to the survey design, wages data is available for only one quarter, usually the first quarter, of each year. Second, survey non-response generates missing wage observations for 15.7% of employed individuals. We replicate these features in the simulated sample by replacing the simulated wage draws with missing values in all non-first quarter periods. We make the same replacement for a random 15.7% of the first-quarter wage observations for employed individuals.

transition from full-time to part-time work, and vice versa, and therefore is informative about the intensive margin friction parameters. The previous wage measure in Model 2 and the education variable in Model 3 are highly correlated with current net income. Thus, the parameters in this model, and the intercepts in the other models, summarize the importance of consumption in driving behavior. These parameters thus provide identifying information about the consumption interaction terms, and coefficient of relative risk aversion and the variance of the transitory preference shocks. The relationship between employment and retirement outcomes and previous unemployment, as specificated by Model 4, is informative about the extent to which employment and retirement outcomes are driven by permanent unobservables. Model 5 provides identifying information about the impact of children on preferences.

The multinomial logit model of the joint employment and retirement outcomes of cohabiting individuals has 12 alternatives, reflecting all possible combinations of male and female employment and retirement outcomes. Due to the large number of alternatives, we do not include explanatory variables in this model. The auxiliary model parameters therefore consist of the 11 alternative-specific intercepts. While the individual-level multinomial logit models provide information about men's and women's preferences for the employment and retirement states, the joint model additionally speaks to the complementarity or substitutability between male and female leisure time, and therefore provides identifying information on the preferences of couple households.

4.2.3 Auxiliary Sub-model of Assets

The auxiliary model of assets severs primarily to provide identifying information on the discount factor. We specify:

$$A_{n,t} \sim N\left(x_{n,t}^{a} b^{a}, c_{a}^{2}\right), \tag{21}$$

where $x_{n,t}^{a}$ includes an intercept, measures of the age and education of each adult household member, and the interaction of each variable with a dummy for being a couple household. Conditional on the observables, $x_{n,t}^{a}$, the auxiliary model assumes that the sample wage observations are independent over households. In the estimation sample, assets are observed only in one period. We use the same observation rule when constructing the simulated sample.[33]

[33] We adopt a linear model for wealth rather than, e.g., a tobit model, to minimize the impact of any measurement error in the sample wealth observations.

5 Structural Parameter Estimates, In-sample Goodness of Fit and External Model Validation

5.1 Structural Parameter Estimates

[To be completed]

5.2 In-sample Goodness of Fit

See appendix G.

5.3 External Model Validation

An external model validation exercise provides further support for the estimated model. We follow previous studies, e.g. Todd and Wolpin (2006) and Low and Pistaferri (2010) and validate the structural model by replicating results from the reduced form literature without targeting these estimates directly. In particular, we show that the behavioral responses to key parameters of the Unemployment Insurance system implied by the estimated model are consistent with the findings of previous reduced-form studies exploiting arguably exogenous variation.

In summary, previous research has shown that both the level of benefits, i.e., the replacement rate, and the duration of benefits, influence the future employment behavior of individuals entering unemployment. A relatively large number of studies focusses on the employment effects of changes in the maximum entitlement period either exploiting changes over time or age discontinuities in the maximum entitlement period (Table XX presents the discontinuities for Germany). Depending on the institutional setting results slightly differ, but in general the analyses find that a one week increases in the maximum duration of benefits increases the duration of non-employment of 0.05-0.2 of a week. For example, Schmieder *et al.* (2012, Table II) find for Germany during the sample period of our study that a one week extension in the duration of benefits increases the average duration of non-employment by 0.1-0.13 of a week for individuals in their 40s.[34] Estimating the same quantity using data from Austria, Lalive *et al.* (2006, Table 5) find a value of 0.05 at ages 40-49 and 0.1 age at 50 and above; the larger responses for older individuals are attributed to the early retirement options available to individuals in their 50s and 60s. This larger effect for older unemployed is supported by several studies which focus on unemployed close to retirement, e.g. Lalive (2008) and it is consistent with the literature describing unemployment as a stepping stone into retirement. Grogger and Wunsch (2012) provide evidence for Germany that unemployed close to retirement strongly react to changes in the entitlement period.

Regarding the level of benefits, previous empirical evidence is less clear cut. In particular for Germany there is hardly any evidence on this margin, in fact there is very little variation in replacement rates over time or by demographic characteristics which could be used for identification. One exception is Hunt (1995) who focusses on a reduction of the replacement ratio for unemployed without children in the beginning of the 1980s. She

[34] Schmieder *et al.* (2012) show in more detail that the size of their effects is consistent with the international literature. The same evidence in given in the survey by Tatsiramos and van Ours (2012)

does not find a significant effect of the replacement ratio on the overall exit rate our of unemployment but shows that a reduction in the replacement rates leads to an increase into retirement. In general the international literature reports a 10 percentage point increase in the level of benefits to increase the duration of non-employment by 0.5-1.5 of a week. For example, Lalive *et al.* (2006, Table 5) find that a 10 percentage point increase in the level of benefits increases the average non-employment duration by 0.63 of a week.[35]

Based on the estimated structural model we derive the same marginal effects as reported in the reduced form literature for individuals entering non-employment at age 40 and at age 50. In particular, we simulate employment and retirement behavior, i.e duration of non-employment and time until retirement, subsequent to entering non-employment under two regimes: a pre-reform regime in which the year 2000 Unemployment Insurance rules apply; and a post-reform regime in which individuals experience an unanticipated change in the level or duration of Unemployment Insurance benefits. Specifically, in the post-reform scenario, behavior at and prior to the age of interest, i.e., 40 or 50, is simulated based on the same year 2000 Unemployment Insurance rules however after this age threshold the non-employed experience an unanticipated change in level or duration of Unemployment Insurance. The design of this simulation ensures that the inflow samples are identical in the pre- and post-reform regimes and therefore a comparison of behavior across regimes delivers the causal effect of the Unemployment Insurance reform. In our simulations we follow Schmieder *et al.*, 2012 and censor spells at 36 months.

The first panel of Table 2 shows the behavioral responses induced by an extension of maximum Unemployment entitlement of one week. Based on the structural model we simulate an extension of duration in unemployment by 0.08 weeks for individuals entering unemployment at the age of 40, and 0.2 weeks at the age of 50. These findings are consistent with the results of the reduced form literature. In particular, for unemployed at the age of 40 we can replicate the result of Schmieder *et al.* (2012) and, in line with Lalive *et al.* (2006) and Lalive (2008) we find higher effects for older unemployed. As our simulations show the latter effect is related to the retirement behavior: we find for the unemployed aged 50 that retirement is postponed by 0.08 weeks. As expected the retirement effect is not present at younger years. Our simulations show no clear pattern by gender but in general the effects for men and women are not markedly different, Schmieder *et al.* (2012) show that effects are slightly higher for women.

In the second panel of Table 2 we present the employment and retirement effect of

[35]Early studies estimated employment effects of the level and duration of Unemployment Insurance benefit without appeal to exogenous policy changes, age discontinuities or other quasi-natural sources of variation. In this vein and for the US, Katz and Meyer (1990) report that a one week increase in duration increases the duration of unemployment by 0.16-0.2 of a week. Moffitt (1985) reports a value of 0.15 for the same quantity.

	Age (years) at start of spell			
	40	50	40	50
	Duration of non-employment		Time until retirement	
Duration of Unemployment Insurance Benefits:				
Effect of a 1 week extension of maximum UI entitlement period on average spell duration (weeks):				
Model prediction:				
All spells	0.08	0.20	0.00	0.08
Men	0.13	0.20	0.00	0.10
Women	0.08	0.21	0.00	0.06
Previous studies:	0.05-0.1 effect on non-employment duration for prime age individuals; evidence of delayed retirement for older individuals.			
Level of Unemployment Insurance Benefits:				
Effect of a 10 percentage point increase in level of UI benefits on average spell duration (weeks):				
Model prediction:				
All spells	0.47	2.83	0.11	1.19
Men	0.62	2.78	0.22	1.39
Women	0.31	2.88	0.00	0.98
Previous studies:	0.5-1.5 effect on non-employment duration for prime age individuals; evidence of delayed retirement for older individuals.			

Notes: A spells starts when an individual transitions into non-employment from either full-time or part-time employment. Spells are censored at 36 months (as in Schmieder *et al.*, 2012). Estimated effects are for individuals who were in continuous employment during the 64 months prior to the spell start date.

Table 2: External model validation: Model implied effects of duration and level of Unemployment Insurance benefits.

an increase in the generosity of unemployment insurance. Overall we find that a 10 percentage point increase in the level of benefits increases the average non-employment duration by 0.47 of a week at the age of 40 and a considerably larger effect of 2.83 weeks at the age of 50. As mentioned above, the causal evidence on this margin is relatively scarce, so it is difficult to convincingly validate our model on the replacement effects. Still it is worth mentioning that our simulated effects are in line with the previous findings and that we again can show the dominant retirement effect for the unemployed aged 50 which is in line with the results of Hunt (1995).

6 Welfare-improving Policy Reforms

Drawing on the estimated model, we investigate how welfare varies in the design of the public insurance system, what the optimal public insurance system looks like and how conclusions concerning optimality depend on the availability of intra-household insurance from household labor supply.

6.1 Welfare Metric

We use an equivalent variation-based measure of the welfare (Low *et al.*, 2010, use a similar welfare measure). Consider environment E, defined by a particular combination of public and private insurance opportunities. The welfare value of environment E is the fraction by which life-time consumption in a baseline environment must be scaled to equate expected life-time utility in the baseline environment with expected life-time utility in environment E. Formally, let $(\widetilde{m}_{n,t}, \widetilde{D}_{n,t}, \widetilde{S}_{n,t})$ denote household consumption, the employment and retirement outcomes of the household members and the search intensities of the household members in the baseline environment. The welfare value attached to environment E is the value of w^E that solves:

$$E\left[\sum_{t=\tau_n^0}^{\overline{T_n}} u^{H(n,t)}(\widetilde{m}_{n,t}w^E, \widetilde{D}_{n,t}, \widetilde{S}_{n,t})\,|\text{Baseline Environment}\right] = E\left[\sum_{t=\tau_n^0}^{\overline{T_n}} u^{H(n,t)}(m_{n,t}, D_{n,t}, S_{n,t})\,|\text{Environment } E\right]. \quad (22)$$

The expectation in 22) is with respect to both the realization of employment and productivity risk in the relevant environment and the distribution of observed and unobservable household characteristics.[36]

6.2 Results

[To be completed]

[36] Our measure of welfare assumes additivity of the utilities of single and couple households. We justify this assumption by noting that given common risk preferences the marginal utility consumption for a single adult household with a non-employed adult household member is equal to the marginal utility of consumption for a couple household in which both spouses are non-employed. This observation suggests a natural equivalence between a single adult household's utility to a couple household utility.

7 Private Insurance and the Optimal Design of Unemployment Insurance and universal Welfare programs

[To be completed]

8 Conclusion

[To be completed]

Appendix

A Job Destructions

As part of the annual SOEP surveys, an individual who left a job the last year is asked the reason for his or her most recent job separation. Based on this variable, we identify involuntary separations, defined as layoffs, plant closures, mutual agreements, and terminations of temporary contracts.[37] We estimate demographic group-specific probabilities of an involuntary separation, conditional on a transition from employment to non-employment.[38] We also estimate quarterly demographic group-specific probabilities of a transition from employment to non-employment. Job destruction rates are obtained by taking the product of the probability of an involuntary separation, conditional on a move from employment to non-employment, and the quarterly probability of a transition from employment to non-employment. Table 3 reports the estimated job destruction rates. There is substantial between-group variation in job destruction rates: being highly educated or aged under 50 is negatively associated with the job destruction rate.

[37]The survey questions ask only the reason for leaving the last job. We assume that, conditional on the demographic group, the most recent separation is representative of all transitions.

[38]Job-to-job transitions are therefore excluded.

	Men	Women
High education, Age≥50	1.40	1.45
High education, Age<50	0.68	1.21
Medium education, Age≥50	1.27	1.87
Medium education, Age<50	1.10	1.72
Low education, Age≥50	2.09	2.68
Low education, Age<50	1.14	1.79

Notes: Job destruction rates are the product of the conditional probability of an involuntary separation, conditional on a move into non-employment, and the quarterly probability of a transition from employment to non-employment. Estimation draws on the SOEP sample for 1991-2005. Probability models are Probits with time effects group specific effects for the 6 demographic groups listed in this table. High, Medium and Low estimation are defined in Table 4. All estimations are conducted separately for men and women. The probability of an involuntary separation, conditional on a move from employment to non-employment, is estimated using 1170 (1679) observations on men (women). The quarterly probability of a transition from employment to non-employment is estimated using 204251 (165642) observations on men (women).

Table 3: Estimated quarterly job destruction rates (percentages, year 2000).

B Further Details of the German Tax, Transfer and Child-care Systems

This appendix describes the legislation of social security contributions, income taxation, pension benefits, child benefits and child care costs in Germany. As mentioned in Section 2.3.2 the maximum entitlement for Unemployment changed in 1997. In order to account for the variation in the working incentives induced by this reform, we distinguish in the model two periods, 1991 - 1997 and 1997 - 2005. In particular we approximate the pre-reform tax and transfer system with the legislation of the year 1995 and the post-reform with the system of the year 2000. All relevant aspects of the tax and transfer system are hard coded in the model and we simulate for each household, conditional on the household characteristics, such as marital status or number of children, the respective period specific net household income.

Social Security Contributions (SSC)

In each month, an individual's income from employment is subject to social security deductions for health, unemployment and pension benefits which in total amount to about 20% of individual gross earnings. The contributions are shared between the employee and employer. Social security contributions are capped, and the upper level of monthly earnings subject to SSC is higher in west Germany than in the east (4300 Euros compared to 3550 Euros in the year 2000).

Income taxation

In contrast to SSC, income tax is computed on an annual basis and at the household level. An individual's annual taxable income is defined as the sum of gross income from employment above an exemption threshold, gross income from assets above a disregard and income from renting. Moreover SSC up to a maximum amount are deducted. An individual's annual income tax liability is obtained by applying the income tax function to taxable income. The income tax function is a progressive smooth function of taxable income above a further exemption threshold. The exemption threshold increased between 1995 and 2000 from 4050 Euro to 6876 Euro while, over the same period, the top marginal tax rate decreased from 53% to 51%. In addition to income taxation, individuals pay an extra tax (Solidaritaetszuschlag) to finance the cost of German reunification. This extra tax was 7.5% in the year 1995 and in the year 2000 5.5% of income tax payments. In Germany married households are tax jointly with full income splitting. That implies that the income tax of a married couple is calculated by applying the tax function to half of the sum of the spouses' incomes; this amount is then doubled to determine the tax amount of the couple.

Pension system

German public pension benefits reflect employment and earnings outcomes prior to retirement. An individual accumulates one pension point for every year of employment over the life-cycle. 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.

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. During the sample period, around 30% of income from pension benefits is subject to income tax.

Our model recognizes that early retirement may be possible on grounds of gender, working history, or due to disability . 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. In general, the value of the pension from early retirement 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.

Our model reflects as well that working beyond the full pensionable age is possible. 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.

Child Benefits and Child-care Cost

For each dependent child households receive child benefits of 150 Euro per months which directly increase the net household income.[39] Child benefits are withdrawn from universal Welfare which include a slightly higher child component. Child benefits do not affect Unemployment Insurance payments.

In our model we include child care costs. Household with pre-school age children need to pay for full time child care if both parents work full time, and part-time care if the mother works part-time instead. The same rule applies for single mothers. In Germany public child care is subsidized however the access to public subsidized child care is limited, in particular for children younger than three years. We follow Wrohlich (2011) and account for the rationing of subsidizes child care and assume that rationed households need to buy private child care. In particular we calculate the average child care cost using the estimates of rationing from Wrohlich (2011). She shows that on average about 37% of children younger than three and about 10% of children between the age of three and six do not have access to subsidized child care and need to buy child care on the private market at an average costs of 5 Euro per hour. This implies the expected child care cost per month for children younger than the age of three amount to 183 Euro for part time

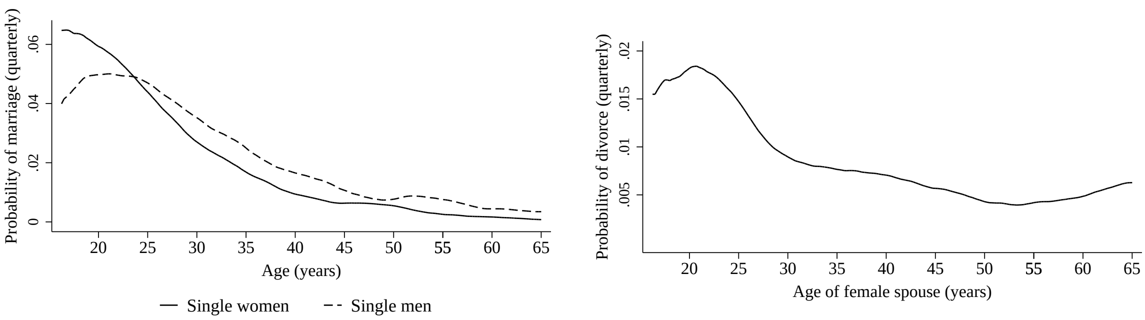
[39]Instead of child benefits household can choose a child allowance for the calculation of income tax. This is only attractive for a small fraction high income households. Without affecting the results we do not model this rule.

and 397 Euro for full time care and for children aged between three and six years the costs are 90 Euro for part-time and 167 Euro for full time care.

C Evolution of Household Type and Children

Marriage and Divorce

Marriages and divorces are assumed to follow exogenous processes. Marriage probabilities are estimated using a Lowess regressions of marriage on age, using a sample of individuals who were in single-adult households in the previous period. Similarly, divorce probabilities are estimated using Lowess regressions of divorce on the age of the female spouse age, using a sample of women who were in couple households in the previous period. Figure 2 illustrates the estimated quarterly marriage and divorce probabilities.

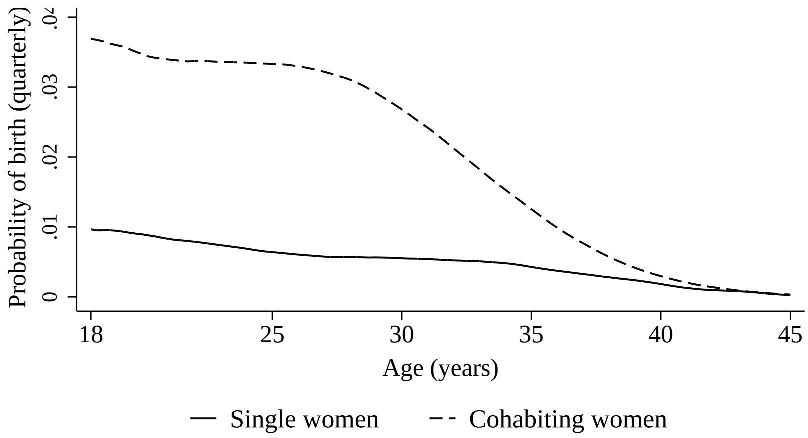


Notes: Marriage and divorce probability estimates were obtained using a sub-sample consisting of individuals aged under 65 and not in full-time education.

Figure 2: Estimated quarterly marriage and divorce probabilities.

Fertility

Births are assumed to follow an exogenous process. Further, women who are in full-time education, or aged over 45, or who have given birth to a child in the last year, are assumed to have zero probability of a birth in the current quarter. Birth probabilities are estimated using Lowess regressions of an indicator a birth in the current quarter on the woman's age. Separate Lowess regressions are estimated for women in single-adult and couple households. Figure 3 illustrates the estimated quarterly birth probabilities.



Notes: Birth probability estimates were obtained using a sub-sample consisting of women aged 45 or under, not in full-time education, and who have not given birth to a child in the last year.

Figure 3: Estimated quarterly birth probabilities.

D Sample Construction and Descriptive Statistics

When constructing the sample, we draw on two district aspects of the survey information on employment and retirement outcomes. First, in each survey individuals were asked to report their employment and retirement status in each month of the previous calender year. From this information, we form indicators of full-time work, part-time work, non-employment and retirement for each individual and for each quarter of the previous calender year. We use an individual's employment and retirement status in the first month of the quarter to define the quarterly outcome. Consistent with the theoretical framework, the category of non-employment in the sample contains all non-retired non-working individuals. We construct the sample to ensure that retirement is an absorbing state: an individual is coded as retired from the date at which he or she first reports being retired. Second, at the point of sample entry, individuals were asked to report their annual employment status, i.e., full-year of work, part-year of work, or no work, for each year between the school leaving age and the survey date. Using this information, we form an accurate measure of years of labor market experience at the time of survey entry. We augment this variable in line with in-sample employment outcomes to obtain our experience variable.

The gross hourly wage is defined as gross earnings, including overtime pay, in the month prior to the survey date divided by reported contractual working hours, including hours of paid overtime, during the same period. Wages are thus sampled only for those individuals who are employed in the month prior to the survey date. Our measure of household assets is the combined net value of a household's financial, housing and tangible assets. Information on these asset classes was collected from a detailed household questionnaire administered as part of the 2002 SOEP survey. Our measure of household assets is therefore cross-sectional. We use the Retail Price Index to express the values of all nominal variables in year 2000 prices. Table 4 provides descriptive statistics, and gives details about the additional variables used in the empirical analysis.

Variable	Single men		Single women		Cohabiting men		Cohabiting women	
	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean
Age (years)	42095	39.59	60649	42.62	240251	44.47	247989	43.18
Education (years)	42095	12.21	60649	11.83	240251	11.98	247989	11.56
High educ.	42095	0.30	60649	0.25	240251	0.23	247989	0.20
Medium educ.	42095	0.59	60649	0.57	240251	0.65	247989	0.60
Low educ.	42095	0.11	60649	0.18	240251	0.11	247989	0.20
Experience (years)	42095	16.63	60649	17.03	240251	22.49	247989	16.24
Full-time employed (FT)	42095	0.71	60649	0.44	240251	0.77	247989	0.32
Part-time employed (PT)	-	-	60649	0.13	-	-	247989	0.24
Retired (RT)	42095	0.11	60649	0.23	240251	0.15	247989	0.12
Non-employed (NE)	42095	0.18	60649	0.20	240251	0.08	247989	0.32
Assets (Euros)	948	54118	1296	42965	4731	147930	4942	154951
Wage (gross, hourly)	5053	14.56	6482	12.27	34167	15.57	24685	11.21
Age 1st Child (years)	-	-	16072	11.33	114195	10.28	109464	10.70
Age 2nd Child (years)	-	-	5580	8.72	60188	7.50	57726	7.80
Age 3rd Child (years)	-	-	1230	6.88	14067	5.93	13521	6.14

Notes: Summary statistics are for individuals aged 16-65 inclusive. High, medium and low education are defined as years of education of 13 or more, more than 10.5 and less and 13, and 10.5 or fewer respectively. Any children beyond the first three are neglected, as are any children residing with single men.

Table 4: Descriptive statistics for the SOEP sample 1991–2005.

E Construction of the Simulated Sample

Starting with the SOEP data, one person in each couple household is randomly designated to be the "reference person". Adults in single-adult households are also assigned to be reference persons. We then use the following two-stage procedure to construct a life-cycle trajectory for each reference person.

First, we simulate the evolution of household type and children over the period between the reference person entering the labor force and reaching age 65 years. If and when reference person starts cohabiting, we draw the years of education of the new spouse from the relevant conditional distribution. Couple households are constructed such that the male spouse is 2.5 years older than the female spouse.[40] At this point, we also simulate the new spouse's household type and fertility at each period prior to the transition into the reference person's household. Recall, household type, children and years of education are taken to be exogenous. The parameters that describe these processes are estimated prior to the structural estimation (see Appendix C). Therefore, we are able to simulate the life-cycle profiles of all exogenous variables prior to estimation of the structural parameters. This facilitates computation.

Second, using the structural model with a specific vector parameter values, we simulate the life-cycle trajectories of accepted wages, employment and retirement outcomes and household wealth for all households that contain a reference household member. In the case of couple households, outcomes are simulated for all adult household members. Importantly, we also use the structural model to simulate the wages, employment and retirement outcomes and assets for all individuals in any household that contains a person who subsequently cohabits with a reference person, or that contains someone who subsequently cohabits with someone who later cohabits with a reference person. In doing so, we ensure that a reference person's new spouse's previous labor market outcomes, retirement status and asset holdings are consistent with the structural process that describes behavior subsequent to joining the reference person's household.

We estimate the parameters of the auxiliary model using a simulated sample formed of the reference persons and their household members in periods in which the reference person's household is present in the estimation sample. The sample construction ensures that the empirical distributions of reference person age, education and gender in the simulated and observed samples coincide.

F Solution Method

We approximate the value function, required in construction of the simulated samples, using backwards recursion, Monte Carlo integration and interpolation.

For each household type, i.e., single-adult or couple household, solution starts at the compulsory retirement age, T_r, and then works backwards.[41] We choose vectors of the age T_r state variables, denoted by q_{l,T_r} for $l = 1, .., L$.[42] Given wage and fertility shocks z and f, the terminal value at each grid point is given by:

$$V^H_{T_r}(q_{l,T_r}, z, f) = \sum ... \tag{23}$$

[40]This figure reflects the average male-female age difference for couple households in the SOEP estimation sample.

[41]For couple households, solution starts from the compulsory retirement age of the younger, female, spouse.

[42]Estimation uses 10,000 grid points.

Next, we integrate out age-T_r wage and fertility shocks:

$$\begin{aligned} V_{T_r}^H(q_{l,T_r}) &= \underset{z,f}{E}\left[V_{T_r}^H(q_{l,T_r},z,f)\right] \\ &= P_{T_r}^H(\text{Birth})E_z\left[V_t^H(q_{l,T_r},z,f=1)\right]+(1-P_{T_r}^H(\text{Birth}))E_z\left[V_{T_r}^H(q_{l,T_r},z,f=0)\right] \end{aligned} \quad (24)$$

Integration with respect to the wage shock, z, is accomplished using Monte Carlo integration. Let z^r for $r = 1,..,R$ denote draws from the distribution of permanent wage shocks.[43] The simulated counterpart to $E_z\left[V_{T_r}^H(q_{l,T_r},z,f)\right]$ is given by:

$$\widetilde{V}_{T_r}^H(q_{l,T_r},f=j) = \frac{1}{R}\sum_{s=1}^{S} V_{T_r}^H(q_{l,T_r},z^r,f=j) \text{ for } j=0,1. \quad (25)$$

Let $W(q_{l,T_r})$ be a vector that contains functions of the grid point q_{l,T_r}. We use the following approximation:

$$V_{T_r}^H(q_{l,T_r}) \simeq \widehat{\lambda}_{t'}W(q_{l,T_r}). \quad (26)$$

The parameters $\widehat{\lambda}_{T_r}$ that approximate the value function are chosen to minimize the Ordinary Least Squares criterion function:

$$\widehat{\lambda}_{T_r} = \text{argmax}_\lambda \sum_{l=1}^{L}\left(V_{T_r}^H(q_{l,T_r}) - \lambda W(q_{l,T_r})\right)^2. \quad (27)$$

$W(q_{l,T_r})$ contains 265 variables connected to couple households, 157 variables connected to female-headed single households and 127 variable connected to male-headed single households.

The design of $W(q)$ is a key factor in determining the accuracy of the value function approximation. We used difference specifications of $W(q)$ for single men, single women and couple households. $W(q)$ contains a total of X functions of the state values for single men, X for single women and Y for couple households. In the case of single men, among the variables included in $W(q)$ are a fine spline of household wealth, indicators detailing the man's previous employment and retirement status, measures of the man's Unemployment Insurance entitlement, and the man's current market wage. The wage provides an important summary statistic of the strength of the incentive to work, and therefore we include the wage interacted with previous employment and retirement status of household members and with the measures of Unemployment Insurance entitlement. For single women, we additionally include transformations of the child related state variables. For couple households, we include the male and female variables, as for single-adult households, and we additionally include interactions between the man and woman's previous employment and refitment outcomes.

[43] The Monte Carlo integration uses 20 antithetic draws.

Moving backwards, we obtain the age-t value function at grid point $q_{l,t}$ using:

$$V_t^H(q_{l,T_r}, z_t, f_t) = \max_S \left\{ \sum_k P(G_k|S) \max_{D \in G_k, m} \left\{ u^H(m, D, S) + \delta \widehat{\lambda}_{T_r} E[W(q_{l,t'})|m, D, q_{l,t}, z, f] \right\} \right\}, \tag{28}$$

where $t' \equiv t+1$. In (28) we made the substitution:

$$E[V_{t'}^H(q_{l,t'})|m, D, q_{l,t}, z, f] = \widehat{\lambda}_{t'} E[W(q_{l,t'})|m, D, q_{l,t}, z, f]. \tag{29}$$

In doing so, we used the linearity of the value function approximation in the parameter vector $\widehat{\lambda}_{t'}$.[44] Evaluation of $E[W(q_{l,t'})|m, D, q_{l,t}, z, f]$ is straight forward. Conditional on $m, D, q_{l,t}, z$ and f, the vast majority of the variables that appear $W(q_{l,t})$ have know values. For example, experience, assets, and the Unemployment Insurance entitlement period evolve in a deterministic fashion. However, job destruction status and retirement eligibility are stochastic. Given that these are independent binary variables, it is straightforward to compute the expectations of the functions of these variables that appear in $W(q_{l,t})$. Wage and fertility shock as integrated from (28) as described by (24) and (25). Finally, the value function approximation is given by:

$$\widetilde{V}_t^H(q_{l,t}) \simeq \widehat{\lambda}_t W(q_{l,t}) \quad \text{where} \quad \widehat{\lambda}_t = \text{argmax}_\lambda \sum_{l=1}^{L} \left(V_t^H(q_{l,t}) - \lambda W(q_{l,t}) \right)^2. \tag{30}$$

[44]X discuss value function approximation using sieve methods and exploit the same linearity property.

G Internal Goodness of Fit

	Fitted			Observed		
	Age $\leq$ 30	30 $<$ Age $\leq$ 45	45 $<$ Age $\leq$ 65	Age $\leq$ 30	30 $<$ Age $\leq$ 45	45 $<$ Age $\leq$ 65
Log accepted wages - Men						
Mean	2.46	2.53	2.58	2.49	2.69	2.71
Standard deviation	0.39	0.39	0.40	0.36	0.43	0.46
10^{th} percentile	1.97	2.04	2.07	2.02	2.15	2.13
25^{th} percentile	2.20	2.27	2.31	2.28	2.41	2.42
50^{th} percentile	2.46	2.53	2.58	2.51	2.67	2.67
75^{th} percentile	2.72	2.80	2.84	2.72	2.95	2.99
90^{th} percentile	2.96	3.03	3.08	2.93	3.24	3.34
Log accepted wages - Women						
Mean	2.20	2.27	2.32	2.30	2.40	2.40
Standard deviation	0.39	0.40	0.41	0.36	0.41	0.42
10^{th} percentile	1.68	1.74	1.79	1.81	1.82	1.81
25^{th} percentile	1.93	1.99	2.03	2.06	2.11	2.10
50^{th} percentile	2.19	2.27	2.32	2.32	2.41	2.40
75^{th} percentile	2.47	2.54	2.60	2.54	2.67	2.67
90^{th} percentile	2.71	2.80	2.85	2.75	2.91	2.93
Household assets						
Mean	13944.48	46857.11	87065.55	29533.13	70242.88	87576.21

Notes: Wage-based quantities are tabulated according to the individual's age. Mean household assets are tabulated according to the age of the randomly-chosen household reference person.

Table 5: Internal goodness of fit I: wages and assets.

	Fitted			Observed		
	Age $\leq$ 30	30 < Age $\leq$ 45	45 < Age $\leq$ 65	Age $\leq$ 30	30 < Age $\leq$ 45	45 < Age $\leq$ 65
Single men						
$FT_t \mid FT_{t-1}$	0.98	0.97	0.97	0.97	0.98	0.96
$FT_t \mid NE_{t-1}$	0.24	0.25	0.13	0.12	0.10	0.05
$NE_t \mid FT_{t-1}$	0.02	0.03	0.01	0.03	0.02	0.02
$NE_t \mid NE_{t-1}$	0.76	0.75	0.84	0.88	0.90	0.92
$RT_t \mid FT_{t-1}$	0.00	0.00	0.02	0.00	0.00	0.01
$FT_t \mid NE_{t-1}$	0.00	0.00	0.02	0.00	0.00	0.03
Cohabiting men						
$FT_t \mid FT_{t-1}$	0.99	0.99	0.98	0.98	0.99	0.97
$FT_t \mid NE_{t-1}$	0.09	0.06	0.01	0.17	0.13	0.06
$NE_t \mid FT_{t-1}$	0.01	0.01	0.02	0.02	0.01	0.02
$NE_t \mid NE_{t-1}$	0.91	0.93	0.94	0.83	0.87	0.89
$RT_t \mid FT_{t-1}$	0.00	0.00	0.01	0.00	0.00	0.01
$FT_t \mid NE_{t-1}$	0.00	0.01	0.05	0.00	0.00	0.05
Single women						
$FT_t \mid FT_{t-1}$	0.97	0.99	0.97	0.97	0.97	0.96
$FT_t \mid PT_{t-1}$	0.01	0.02	0.01	0.06	0.05	0.04
$FT_t \mid NE_{t-1}$	0.06	0.07	0.02	0.06	0.05	0.02
$PT_t \mid FT_{t-1}$	0.00	0.00	0.01	0.01	0.01	0.01
$PT_t \mid PT_{t-1}$	0.64	0.94	0.95	0.85	0.92	0.91
$PT_t \mid NE_{t-1}$	0.03	0.05	0.02	0.03	0.04	0.02
$NE_t \mid FT_{t-1}$	0.03	0.01	0.01	0.03	0.02	0.02
$NE_t \mid PT_{t-1}$	0.35	0.04	0.01	0.09	0.03	0.03
$NE_t \mid NE_{t-1}$	0.92	0.88	0.89	0.90	0.90	0.92
$RT_t \mid FT_{t-1}$	0.00	0.00	0.01	0.00	0.00	0.02
$RT_t \mid PT_{t-1}$	0.00	0.00	0.03	0.00	0.00	0.02
$RT_t \mid NE_{t-1}$	0.00	0.00	0.07	0.00	0.01	0.04
Cohabiting women						
$FT_t \mid FT_{t-1}$	0.93	0.96	0.96	0.95	0.96	0.95
$FT_t \mid PT_{t-1}$	0.02	0.01	0.00	0.04	0.02	0.02
$FT_t \mid NE_{t-1}$	0.01	0.02	0.01	0.03	0.02	0.01
$PT_t \mid FT_{t-1}$	0.02	0.02	0.02	0.01	0.02	0.01
$PT_t \mid PT_{t-1}$	0.96	0.97	0.97	0.91	0.95	0.94
$PT_t \mid NE_{t-1}$	0.00	0.01	0.00	0.04	0.04	0.01
$NE_t \mid FT_{t-1}$	0.05	0.02	0.02	0.03	0.02	0.02
$NE_t \mid PT_{t-1}$	0.02	0.01	0.02	0.05	0.03	0.03
$NE_t \mid NE_{t-1}$	0.99	0.97	0.96	0.93	0.94	0.95
$RT_t \mid FT_{t-1}$	0.00	0.00	0.00	0.00	0.00	0.01
$RT_t \mid PT_{t-1}$	0.00	0.00	0.01	0.00	0.00	0.01
$RT_t \mid NE_{t-1}$	0.00	0.00	0.03	0.00	0.00	0.02

Table 6: Internal goodness of fit II: between-state transition rates.

	Fitted			Observed		
	Age ≤ 30	30 < Age ≤ 45	45 < Age ≤ 65	Age ≤ 30	30 < Age ≤ 45	45 < Age ≤ 65
Single men						
FT	0.88	0.88	0.64	0.73	0.85	0.54
NE	0.12	0.12	0.08	0.27	0.14	0.14
RT	0.00	0.00	0.28	0.00	0.02	0.33
Experience	4.86	16.23	32.76	3.32	14.29	30.11
Cohabiting men						
FT	0.93	0.89	0.54	0.89	0.93	0.59
NE	0.07	0.09	0.16	0.11	0.07	0.08
RT	0.00	0.02	0.30	0.00	0.00614901	0.33137765
Experience	7.06	17.49	30.73	5.68	16.525324	32.151664
Single women						
FT	0.37	0.65	0.36	0.55493459	0.56285582	0.27944847
PT	0.05	0.12	0.14	0.12	0.20	0.09
NE	0.58	0.22	0.09	0.33	0.21	0.11
RT	0.00	0.00	0.41	0.00	0.03	0.52
Experience	1.79	8.90	18.53	2.97	11.75	21.62
Cohabiting women						
FT	0.21	0.28	0.24	0.45	0.36	0.23
PT	0.08	0.23	0.23	0.18	0.32	0.19
NE	0.71	0.47	0.27	0.37	0.31	0.31
RT	0.00	0.01	0.26	0.00	0.01	0.27
Experience	2.03	6.40	14.49	3.70	10.58	18.18
Single women whose youngest child is aged <3 years						
FT	0.10	0.43	0.00	0.14	0.15	0.00
PT	0.02	0.16	0.00	0.15	0.22	0.00
NE	0.88	0.41	0.00	0.70	0.62	0.00
RT	0.00	0.00	0.00	0.00	0.00	0.00
Experience	1.36	6.31	0.00	2.55	8.00	0.00
Cohabiting women whose youngest child is aged <3 years						
FT	0.11	0.18	0.00	0.12	0.12	0.00
PT	0.09	0.22	0.00	0.22	0.27	0.00
NE	0.80	0.59	0.00	0.66	0.60	0.00
RT	0.00	0.01	0.00	0.00	0.00	0.00
Experience	1.79	5.79	0.00	3.35	8.45	0.00

Table 7: Internal goodness of fit III:
Individual-level employment and retirement outcomes.

	Fitted			Observed		
	Age $\leq$ 30	30 < Age $\leq$ 45	45 < Age $\leq$ 65	Age $\leq$ 30	30 < Age $\leq$ 45	45 < Age $\leq$ 65
Woman NE and Man NE	0.04	0.05	0.03	0.05	0.03	0.03
Woman PT and Man NE	0.01	0.04	0.04	0.01	0.01	0.01
Woman FT and Man NE	0.04	0.06	0.07	0.04	0.03	0.02
Woman RT and Man NE	0.00	0.00	0.04	0.00	0.00	0.01
Woman NE and Man FT	0.36	0.26	0.11	0.32	0.29	0.16
Woman PT and Man FT	0.07	0.17	0.08	0.17	0.30	0.15
Woman FT and Man FT	0.47	0.37	0.16	0.40	0.32	0.17
Woman RT and Man FT	0.00	0.00	0.03	0.00	0.01	0.05
Woman NE and Man RT	0.00	0.01	0.08	0.00	0.00	0.13
Woman PT and Man RT	0.00	0.02	0.10	0.00	0.00	0.05
Woman FT and Man RT	0.00	0.01	0.11	0.00	0.01	0.06
Woman RT and Man RT	0.00	0.00	0.16	0.00	0.00	0.17

Notes: Tabulations are according to the age of the randomly-chosen household reference person.

Table 8: Internal goodness of fit IV:

Employment and retirement outcomes for couple households.

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