Progressive Taxation and Precautionary Saving Over the Life Cycle*

Davud Rostam-Afschar†
Jiaxiong Yao‡

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Abstract

We study the effect of taxes and transfers on precautionary saving over the life cycle. We estimate idiosyncratic labor income risks and structural parameters of an incomplete-markets model for heterogeneous groups. Our simulated model shows that progressive taxation, compared to a revenue-neutral flat taxation, reduces the average savings by 24.6% for a household with median wealth. Despite crowding out part of savings, households are better insured against income shocks under progressive taxation. 60% of permanent shocks and 30% of transitory shocks to pre-government labor income are insured against under progressive taxation. There are sizeable welfare gains on average with progressive taxation but considerable heterogeneity among different subgroups.

Keywords precautionary saving · labor income uncertainty · tax and transfer system · life cycle

JEL Classification D91 · E21 · H31 · H24

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†Department of Economics, Freie Universität Berlin, Boltzmannstr. 20, 14195 Berlin, Germany, and DIW Berlin (e-mail: davud.rostam-afschar@fu-berlin.de).

‡Department of Economics, 440 Mergenthaler Hall, Johns Hopkins University, Baltimore, MD 21218, USA (e-mail: yaojiaxiong06@gmail.com).

1 Introduction

A classical argument for progressive taxation of household labor income is that progressivity provides social insurance. However, at the same time, precautionary saving is a way for households to shield against uninsurable labor income risks. This paper studies the interaction between precautionary savings and tax progressivity in a life cycle model. Taking Germany as an example, we use this model to assess the importance of precautionary saving under a typical progressive taxation system.

The objective of this paper is twofold. First, we identify how progressive taxation affects precautionary saving behavior in general. Second, we quantify the welfare effects of progressive taxation for the case of Germany by comparing two situations. We compare the actual tax and transfer system in Germany—which is progressive—to a counter-factual tax system in which no social insurance occurs, i.e. a flat tax system in our analysis. This comparison gives us a measure of how important social insurance through progressive taxation is.

We address our research question from the perspective of a partial equilibrium life cycle model using data from the German Socio-Economic Panel (GSOEP). In particular, we develop an incomplete markets life cycle model that includes progressive taxation explicitly. In our setup, households understand the structure of the tax schedule and choose their consumption/savings optimally.[1] Social insurance occurs because income risks that households face are subject to progressive taxation.

In particular, we thank Dmytro Hryshko for providing his code, parts of which we extended for the estimation of the income process. This work began while the first author was visiting the Johns Hopkins University in fall 2012, whose hospitality is gratefully acknowledged. No financial support was received for this work. The views expressed here are ours and not necessarily those of anyone else. The econometric and simulation programs that generated all of the results in this paper are available on the author's website, http://rostam-afshar.de/.

[1]See Meissner and Rostam-Afschar (2014) for a discussion.

Therefore, we can trace the effect of social insurance through progressive taxation on precautionary saving in our model.

We shut down the effect that progressive taxation has on labor supply to isolate the social insurance effect. It is beyond the scope of this paper to analyze optimal taxation which is done, e.g., in Krueger and Perri (2011). Our results rather complement other papers which focus on the distortionary effects of progressive taxation on labor supply (e.g. Mirrlees (1971)). This paper contributes to the literature that quantifies the importance of precautionary saving abstracting from taxation (e.g., Carroll and Samwick, 1998; Gourinchas and Parker, 2002; Cagetti, 2003). Closely related to this paper is previous work that studied how asset-based, means-tested welfare programs such as unemployment insurance affect precautionary saving (Hubbard et al., 1995; Engen and Gruber, 2001).[2]

We identify at least two channels through which progressive taxation affects households' saving behavior over the life cycle.[3] First, progressive taxation reduces after-government income uncertainty mechanically. Positive income realizations will be taxed more than negative. A cross section of a cohort at any point in time would have dampened income and consumption inequality under progressive taxation compared to a revenue-neutral flat taxation. We refer to this effect as *cross-sectional effect*. Second, progressive taxation induces an *intertemporal effect* because households will adjust their saving behavior upon observing the reduction in after-government labor income uncertainty. In particular, the desire to hold wealth as a precaution will be smaller under progressive taxation and therefore a smoother consumption path can be chosen.

[2]In the particular case for Germany, for example Fossen and Rostam-Afschar (2013) recognize the empirical importance of progressive taxation but do not take its effects into account.

[3]In this analysis we assume inelastic labor supply to keep the focus on income uncertainty and saving behavior. Adjustments in working hours in response to uncertainty would provide additional insurance and thus confound our analysis.

The overarching effect is that progressive taxation crowds out part of savings by households. Our first main result is that progressive taxation crowds out 24.6% of wealth for a median household on average over the life cycle. Depending on the growth and the risk profiles of pre-government income, however, the effect of progressive taxation on savings varies across households of different subgroups. For instance, the share of savings crowded out by progressive taxation is only 19.1% for college graduates whereas it is 60.0% for blue collars.

Our second main result is that progressive taxation provides more insurance than revenue-neutral flat taxation for all the subgroups we consider. For the total sample, our simulated economy shows that approximately 60% of permanent shocks and 90% of transitory shocks to pre-government labor income are insured against under progressive taxation. In comparison, only 30% of permanent shocks and 70% of transitory shocks are insured against in an economy with a revenue-neutral flat taxation. It is important to recognize the tension between social insurance provided by progressive taxation and self insurance in the form of wealth accumulation. Our results suggest that despite the reduced incentive to do self insurance in an economy with progressive taxation, households are still better insured against pre-government income shocks.

Third, our results show considerable heterogeneity in welfare gains for different subgroups of population when comparing the equivalent income under progressive taxation to that under revenue-neutral flat taxation. For instance, whereas blue collars need to be compensated with 16.5% of equivalent income under progressive taxation to be indifferent under revenue-neutral flat taxation, college graduates would ask for 0.1% more equivalent income under progressive taxation to be indifferent. The results highlight the need to discuss policy implications of progressive taxation for different subgroups separately. In fact, redesigning the tax and transfer system to account for differences in labor income risks, e.g. by age, could be a fruitful endeavor.

This paper is structured as follows. In Section 2, we outline a simple incomplete markets model with taxes and transfers and discuss the mechanism through which the tax and transfer system might affect household saving and consumption. Section 3 introduces our extended model and briefly describes data, estimation procedure and results of key parameters and variables. Our main results are reported in Section 4. Section 5 concludes.

2 Understanding Progressive Taxation: A Three-Period Framework

Before delving into a full-fledged life cycle model, it is useful to consider the effect of progressive taxation using a simple yet informative three-period model. We divide households' life cycle into three periods: early age, middle age and retirement. Informed by the data, we assume that the first period features low income with large permanent shocks, the second period high income with small permanent shocks, and the third period deterministic income. Specifically, the dynamics of permanent income is

$$\begin{aligned} P_1 &= P_0\Psi_1 & \log\Psi &\sim N(-1/2\sigma^2_{\psi,1}, \sigma^2_{\psi,1}), \\ P_2 &= (1+g_2)P_1\Psi_2 & \log\Psi &\sim N(-1/2\sigma^2_{\psi,2}, \sigma^2_{\psi,2}), \\ P_3 &= (1+g_3)P_2, \end{aligned}$$

where P is permanent income, shocks Ψ are drawn from a log-normal distribution with standard deviation $\sigma_{\psi,1} > \sigma_{\psi,2}$, and income growth is $g_2 > 0 > g_3$.

For simplicity, we abstract from transitory shocks for now and assume that pre-government income is equal to permanent income, i.e., $Y_t = P_t, t = 1, 2, 3$. We define the tax and transfer scheme by[4]

$$TX(Y) = Y - \lambda Y^{1-\tau}, \tag{1}$$

where λ measures the level of tax and transfer payments and τ measures the degree of progressivity. Y_t^{at} denotes after-government income. Households have constant relative risk aversion function, $u(C) = C^{1-\rho}/(1-\rho)$ and zero initial wealth, their objective is to maximize expected discounted utility in the three periods. Note that households are ex-ante identical but are ex-post heterogeneous due to permanent shocks to income. To summarize, households' optimization problem is

$$\max_{C_1,C_2,C_3} E[u(C_1) + \beta u(C_2) + \beta^2 u(C_3)],$$
$$C_1 + \frac{C_2}{1+r} + \frac{C_3}{(1+r)^2} = \lambda Y_1^{1-\tau} + \frac{\lambda Y_2^{1-\tau}}{1+r} + \frac{\lambda Y_3^{1-\tau}}{(1+r)^2}.$$

For the numerical exercise below, we assume $g_2 = 0.50$, $g_3 = -0.50$, $\sigma_{\psi,1} = 0.06$, $\sigma_{\psi,2} = 0.02$, $P_0 = 40,000$, gross interest factor $R = 1.06$, discount factor $\beta = 0.96$, coefficient of relative risk aversion $\rho = 1.5$, and we simulate 1,000 households. To focus on the effect of progressivity, for each τ we choose the level of λ such that the total tax revenue of all households over the three periods stays fixed.

[4] Heathcote et al. (2014) shows that this functional form approximates the tax and transfer scheme in the U.S. quite well with $\tau = 0.15$. As will be clear soon, it approximates the German tax and transfer scheme closely as well with a slight modification. Two special cases are worth noting: $\tau = 0$ is a flat tax and $\tau = 1$ is a progressive tax that provides perfect insurance.

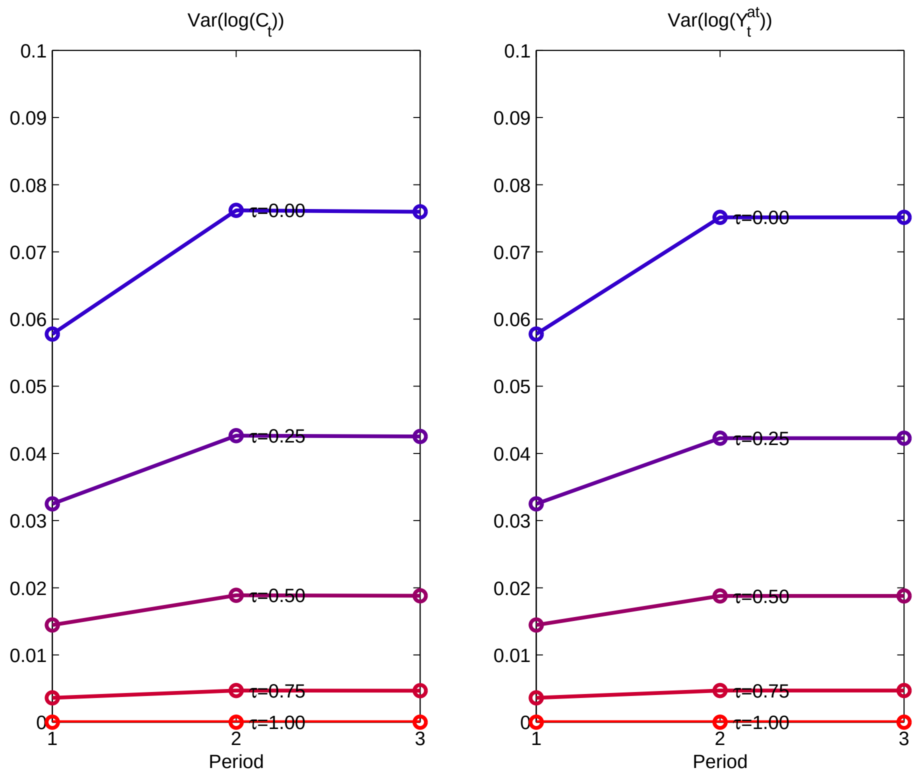

Figure 1: Consumption and After-government Income Inequality in the Three-Period Model.
Source: Own simulation.

Cross Sectional Effect

We start by looking at the effect of progressive taxation on the distribution of income and consumption in each period. Figure 1 shows that as the degree of progressvity increases, consumption inequality and after-government income inequality in each period fall. This is not surprising, because progressive taxation penalizes positive shocks to income while it compensates negative shocks, tightening the after-government income distribution and therefore consumption distribution.

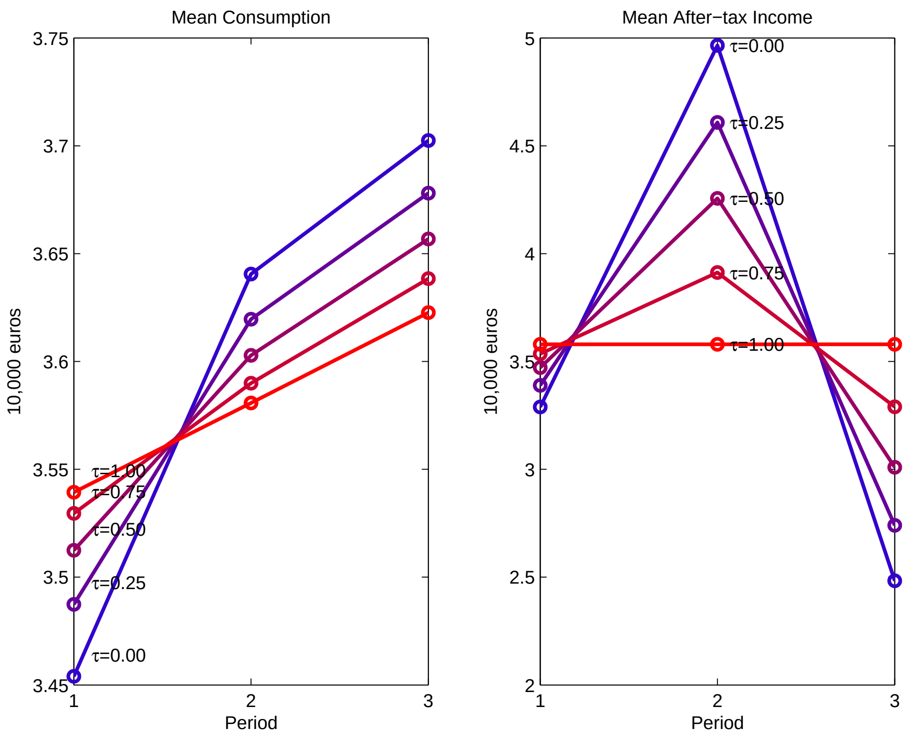

Figure 2: Average Consumption and After-government Income in the Three-Period Model.
Source: Own simulation.

Intertemporal Effect

An often overlooked aspect of progressive taxation is its intertemporal effect, which stems from the interaction of progressivity and uncertainty. It is tempting to think, as we control for the total tax revenue, the mean consumption path would be the same regardless of the degree of progressivity. However, Figure 2 shows that this is not true. In particular, as the degree of progressvity increases, a smoother consumption path is optimal[5]. The key here is after-government income uncertainty. With an increasing

[5]Note that when there is full insurance, consumption growth is $(\beta R)^{1/\rho} = 1.012$ in each period, which follows from the Euler equation.

degree of progressivity, after-government income uncertainty decreases, households do less precautionary saving and therefore the consumption path becomes smoother.

As simple as it is, the three-period model captures two effects progressive taxation has on saving: it tightens the cross-sectional distribution of wealth at a given age and it diminishes wealth accumulation over the life cycle. The three-period model is very stylized, as there is not enough time for wealth accumulation, no borrowing constraint and no bequest motive. To quantify the effect of progressive taxation on saving, we turn to the full-fledged consumption-saving model of households with progressive taxation in the following.

3 Progressive Taxation in a Multi-Period Model and Empirical Evidence

The Household's Problem

This section introduces a discrete-time incomplete markets model of household consumption[6], which will be the basis of our analysis of the effect of progressive taxation on precautionary savings. The economy consists of a finite number of households indexed by i.[7] We assume that households start their economic life in period t_0 and live for T years. Households work for T^{work} years in their life and then enter the stage of retirement when there is a positive probability of death. We assume that the unconditional probability of survival until time t is S_t, so that $S_t = 1$ for $t \leq t_0 + T^{work}$ during households' working life and $S_t < 1$ after retirement. All households die at

[6]See Heathcote et al. (2009) for a review.

[7]In contrast to labor supply decisions that are known to be different in single and couple households, we argue that consumption and saving decisions of single and couple households are negligibly similar.

time $T + t_0$ with certainty[8]. Households have time-separable expected discounted utility from annual consumption C_{it} of

$$E_{t_0}\left[\sum_{t=t_0}^{T+t_0} S_t \beta^{t-t_0} u(C_{it}) + W(A_{iT+t_0+1})\right]. \tag{2}$$

We assume that households have a constant relative risk aversion (CRRA) felicity function

$$u(C_{it}) = \frac{C_{it}^{1-\rho}}{1-\rho}, \tag{3}$$

and a bequest motive that shares the coefficient of relative risk aversion of the felicity function

$$W(A_{iT+t_0+1}) = \alpha \frac{A_{iT+t_0+1}^{1-\rho}}{1-\rho}. \tag{4}$$

Each household is endowed in period t_0 with an initial stock of a risk-free asset A_{t_0} that bears a constant real interest rate r. Capital gains are taxed at a rate τ_A. At every age t, asset accrues and the household receives an exogenous stochastic annual real income Y_{it} where either tax is deducted or benefits are transferred. We combine tax and transfer payments and model the tax and transfer system as a function $TX(\cdot)$ that depends on pre-government labor income Y_{it}, so $TX(Y_{it})$ can be thought of as the real net tax collected by the government when the household's pre-government labor income is Y_{it} (see Subsection 3.2). In each period, having observed gains on asset and its income, the household chooses C_{it}, which is taxed at a rate τ_C, to maximize its expected discounted utility given in equation (2) subject to the

[8] In practice, we set $t_0 = 25$, $T^{work} = 40$, and $T = 65$.

transition equation[9]

$$A_{it+1} = A_{it}(1 + r(1 - \tau_A)) + Y_{it+1} - TX(Y_{it+1}) - (1 + \tau_C)C_{it+1}. \tag{5}$$

The Borrowing Constraint

The borrowing constraint can have a large impact on the consumption and saving of households with low income and/or wealth. We assume that the maximum amount that households can borrow depends on their permanent income. In particular, we assume

$$A_{it} \geq \underline{a} P_{it}. \tag{6}$$

3.1 Income Process

We assume that labor income process has a deterministic component common to all households and an idiosyncratic component. The idiosyncratic component can be decomposed into a permanent and a transitory component as is standard in the literature since Friedman and Kuznets (1954). In particular, we assume that the gross income of each household[10] follows the process

$$Y_{it} = P_{it}\Xi_{it}, \tag{7}$$

$$P_{it} = P_{it-1}\Gamma_t\Psi_{it}. \tag{8}$$

P_{it} is the permanent component of gross labor income. Γ_t is the observed deterministic component of gross labor income and is assumed to be common for all households.

[9] In addition to the natural borrowing constraint here, we also considered the artificial borrowing constraint that binds at zero, however our main results turned out to be similar.

[10] Recall that we assume unitary households, see Haan and Prowse (2010) for an example where different income processes for singles and couple households are specified.

We assume that the transitory shocks and the permanent shocks are mutually independent. For simplicity, we further assume that after retirement, pre-government income becomes deterministic with shocks in equations (7) and (8) being unity.

Dating back to Lillard and Willis (1978), Lillard and Weiss (1979), MaCurdy (1982), and Abowd and Card (1989), there is a history of fitting ARMA models to panel data[11] to understand the labor income risk facing individuals. Many models assume labor income is the sum of a transitory and persistent shocks, where often the persistent shock is assumed to be a random walk.[12] We follow this literature and allow for a transitory component that is ARMA(1,1). In addition, we allow for age-varying variances of both transitory and permanent shocks, which have been identified to play an important role (see Blundell et al. (2014)).

We use information on household labor income from the waves 1984 to 2012 of the German Socio-Economic Panel (GSOEP), see Appendix F for more details. First, we estimate the median income growth rate (see Appendix F.4). Generally, as shown in Figure 3, pre-government income rises until age 55 and from then on stays roughly constant or declines modestly.

In a second step we estimate pre-government labor income risks for each of these groups. In particular, the process for idiosyncratic log labor income y_t for each household[13] is

$$y_t = p_t + \xi_t. \tag{9}$$

In our specification, the permanent component follows a random walk with inno-

[11]For estimates based on German data, see e.g. Biewen (2005); Myck et al. (2011); Bönke et al. (2014).

[12]MaCurdy (1982), Abowd and Card (1989), Gottschalk and Moffitt (1994), Carroll and Samwick (1997), Meghir and Pistaferri (2004), and Blundell et al. (2008a) all assume a unit root in the persistent component.

[13]We omit the household index i in what follows for legibility.

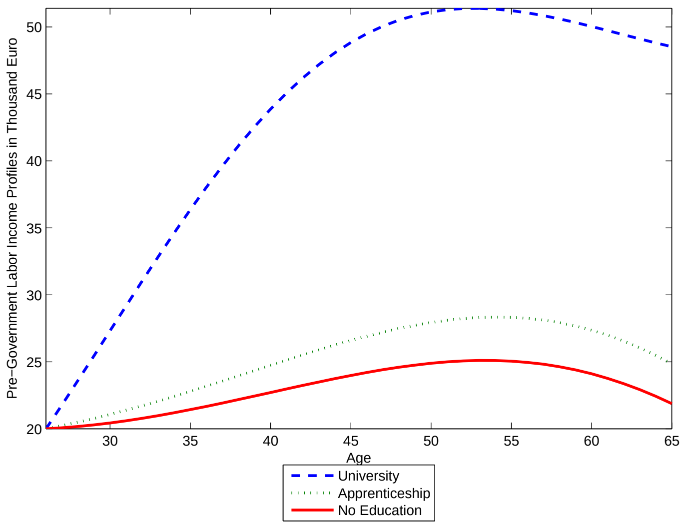

Figure 3: Average of Predicted Income Levels at each Age with Initial Income 20,000 Euro.
Source: Authors' calculations based on the GSOEP (1984-2012).

vation ψ_t

$$p_t = p_{t-1} + \psi_t.$$

The transitory component is described by the following ARMA(1,1) process where L is the lag operator

$$\xi_t = \frac{1+\theta L}{1-\varphi L}\varepsilon_t.$$

Shocks are assumed to be uncorrelated across calendar time, cohort, and age. They are drawn from mean-zero normal distributions with age varying variance according to

$$\psi_t \sim N(0, \sigma^2_{\psi,t}),$$

$$\varepsilon_t \sim N(0, \sigma^2_{\varepsilon,t}),$$

What we want to identify is $\Theta = \{\theta, \varphi, \sigma^2_{\Delta\xi,24}, \sigma^2_{\varepsilon,25}, \ldots, \sigma^2_{\varepsilon,65}, \sigma^2_{\psi,26}, \ldots, \sigma^2_{\psi,64}\}$.

We can identify the parameters using the variance-covariance matrix from ages 25 to 65. As we cannot identify $\sigma^2_{\psi,25}$ and $\sigma^2_{\psi,65}$, we restrict these variances to be equal to $\sigma^2_{\psi,25}$ and $\sigma^2_{\psi,64}$, respectively. In Appendix F.5 we derive the theoretical moments $\gamma_k = E[\Delta y_t \Delta y_{t-k}]$ as

$$\gamma_0 = \sigma^2_{\psi,t} + \sigma^2_{\xi,t}, \tag{10}$$

$$\gamma_1 = \varphi\sigma^2_{\xi,t} + (\theta - 1)\sigma^2_{\varepsilon,t} - \theta(\varphi + \theta - 1)\sigma^2_{\varepsilon,t-1}, \tag{11}$$

$$\gamma_k = \varphi^{(k-a)}\sigma^2_{\xi,t} + (\varphi^{(k-a-1)}(\theta - 1) - \varphi^{(k-a-2)}\theta)\sigma^2_{\varepsilon,t} - \varphi^{(k-a-1)}\theta(\varphi + \theta - 1)\sigma^2_{\varepsilon,t-1}\forall k \geq 2. \tag{12}$$

For estimation, we use the GMM procedure with identity weight matrix.[14] Given a vector of 81 parameters Θ, we can generate a (theoretical) variance-covariance matrix of the vector $(\Delta y_t, \ldots, \Delta y_{t+40})$, denoted by Ω. We compute the empirical variance covariance matrix of the same vector and denote it by $\hat{\Omega}$. Then our objective is to find the set of parameters that minimize $(\Omega - \hat{\Omega})'(\Omega - \hat{\Omega})$.

We present estimates along with standard errors for all groups in Appendix F.5. As we are interested in the life cycle patterns of uncertainty, it is instructive to investigate visually how labor income risks evolve over age for the different subgroups introduced above. Figure 4 illustrates the uncertainty profiles of permanent and transitory shocks for employees. In this exposition the estimates are smoothed using a second order polynomial. The general pattern that we find, and which is documented in a growing literature, is that permanent uncertainty is u-shaped: It is high in young years, possibly increasing towards the end of the life cycle. In our life cycle model,

[14]We use equally weighted minimum distance for reasons explained in Altonji and Segal (1996).

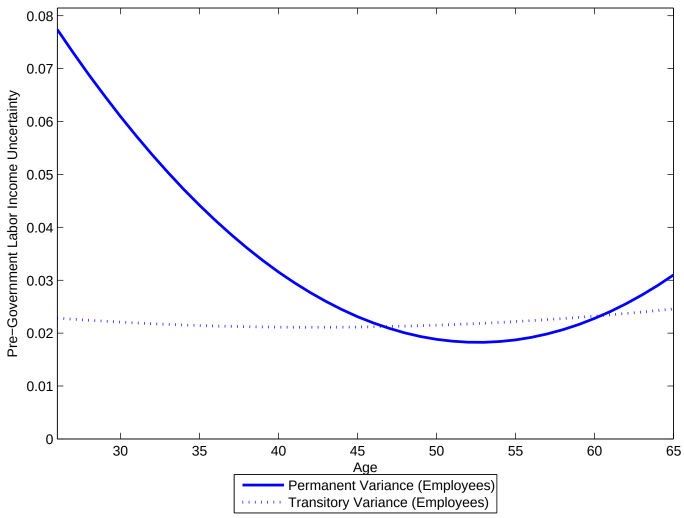

Figure 4: Permanent and Transitory Uncertainty Over the Life Cycle.
Source: Authors' calculations based on the GSOEP (1984-2012).

we want to abstract from business cycle effects. Thus, we take out year effects. This leads to a flat profile of transitory uncertainty over age for most groups.

3.2 Progressive Taxation

As we are interested in how progressivity of the tax and transfer system affects precautionary saving, we specify a parsimonious tax function following the long tradition in public finance (see Feldstein (1969)). Taxes or Transfers are give by

$$TX(Y) = Y - \lambda Y^{1-\tau} \tag{13}$$

We are particularly interested in the parameter τ because it determines the degree of progressivity of the tax system. This implies that disposable (post-government) income $\tilde{Y}$ is a function of pre-government income Y. In fact,

$$\tilde{Y} = \lambda Y^{1-\tau}. \tag{14}$$

From this we see that the elasticity of post-government income with respect to pre-government income is just $(1 - \tau)$ which is also known as the coefficient of residual income progression.

Let us examine further how this parameter measures progressivity by using the definition widely applied in public economics that a tax-transfer function is progressive if the marginal tax rate is larger than the average tax rate for every level of income.

$$TX'(Y) > TX(Y)/Y,$$

which means in our case

$$1 - \lambda(1 - \tau)Y^{-\tau} > 1 - \lambda Y^{-\tau}.$$

Conversely, a tax-transfer function is regressive if the marginal tax rate is smaller than the average tax rate for every level of income.

If $\tau = 0$, the tax and transfer function becomes a flat tax system with the rate of $1 - \lambda$. As the flat tax system turns off all social insurance effects that progressive taxation implies, it is the natural benchmark to study how progressivity of the tax and transfer system affects precautionary saving.

If $\tau > 0$, the tax and transfer system is progressive because the marginal tax rate is greater than the average tax rate. In the main analysis, we compare the actual progressivity of the German tax and transfer system to the flat tax case. Before we describe how we estimate τ for Germany, note that λ shifts the tax function and determines the average level of taxation. Note also that this function has a break-even income level below which in a progressive system the average tax rate is negative. This means that households receive transfers from the government.

Although this function is parsimonious in its parametrization, it gives us a remarkably good representation of the actual tax and transfer system in Germany. To estimate the two parameters, we use data on household pre-government labor income from the GSOEP and of post-government income using the tax transfer calculator "Steuer-Transfer-Mikrosimulationsmodell" (STSM) for wave 2012 (see Steiner et al. (2012)). Pre-government household income includes labor earnings, private transfers like alimony, pension incomes, and income from interests, dividends, and rents. Post-government income equals pre-government income minus income taxes computed using the STSM (including solidarity surcharge, social security contributions, etc.), plus public transfers (social security benefits, unemployment benefits, etc.).

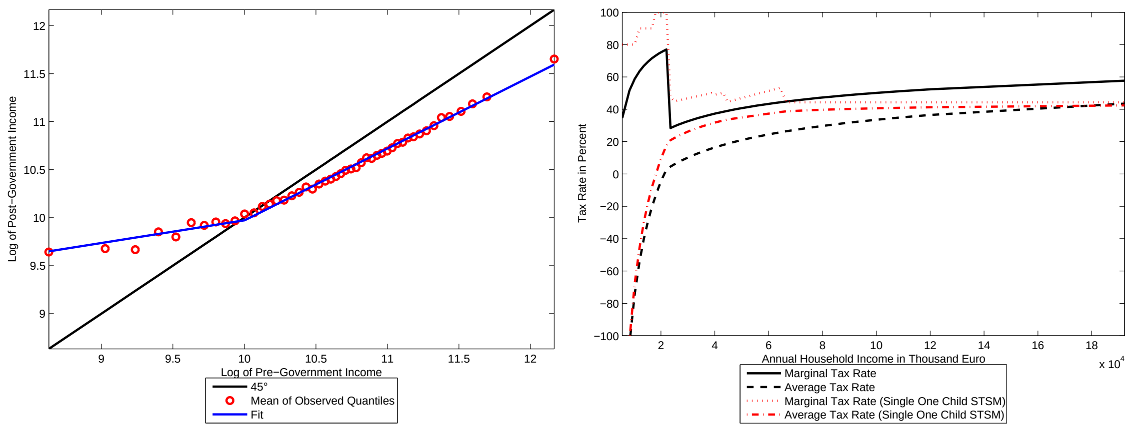

Figure 5: Estimation of the Tax and Transfer Function and Implied Tax Rates.
Source: Authors' calculations based on the GSOEP (2012).

The left graph in Figure 5 shows our estimates and is constructed as follows. We collapse our data into 50 quantiles. Each of the circles represent the mean of the corresponding quantile of the pre-government income, and the mean post-government income across the observations in that same quantile. Then we estimate equation (14) in logs using OLS. Because transfers have a different slope and intercept, we interact $log(Y)$ with a dummy indicating whether transfers have been received or not. The point estimate is $\tau = 0.23$ for the area where no transfers are paid. This is well above the estimate of $\tau^{US} = 0.15$ that Heathcote et al. (2014) find for the USA. This simple model fits the data remarkably well with R^2 as high as 0.994. In the figure a solid blue line shows the model fit and a solid black line the 45 degree line where pre- and post-government income are identical.

The right graph in Figure 5 displays the implied marginal and average tax rates which we obtain from our estimates of τ and λ. The solid black line shows the marginal tax rate, while the dashed black line is the average tax rate. For comparison, the red dotted line shows the marginal tax rates of a single person with one child. Note that these lines are actually not comparable because one is a specific household type and the other is calculated on basis of many different household types. Nevertheless, the comparison gives a rough idea how well our estimates are. The red dashed line displays the average tax rate for the same household. Obviously, the function represents the tax and transfer system quite well.

Of course, equation (14) is not useable to identify the effect of a certain reform or for reform proposals. However, as our aim is to investigate progressivity and not a specific reform, this function is advantageous. In particular, an important advantage of the functional form we use is that the model remains simple, and the trade-offs from increasing or reducing progressivity are transparent. Conducting a taxation exercise using a more complex tax and transfer system is left for future research.

3.3 Calibration of Preferences and Other Parameters

The distribution of wealth, and hence the insurance effect of progressive taxation, depends on households' preferences. In particular, the discount factor affects the amount of wealth accumulation on average and the risk aversion determines the allocation of wealth over the life cycle due to precautionary or consumption smoothing reasons. Despite the importance of households' preferences, the literature remains inconclusive about their values[15]. As the values of households' preferences are central to our results, we estimate the risk aversion and the discount factor simultaneously by matching the median wealth profiles of households. We find the coefficient of relative risk aversion to be 0.6529 for the entire sample and the discount factor 0.9633. Appendix C shows how we use the method of simulated moments to estimate households' preferences.

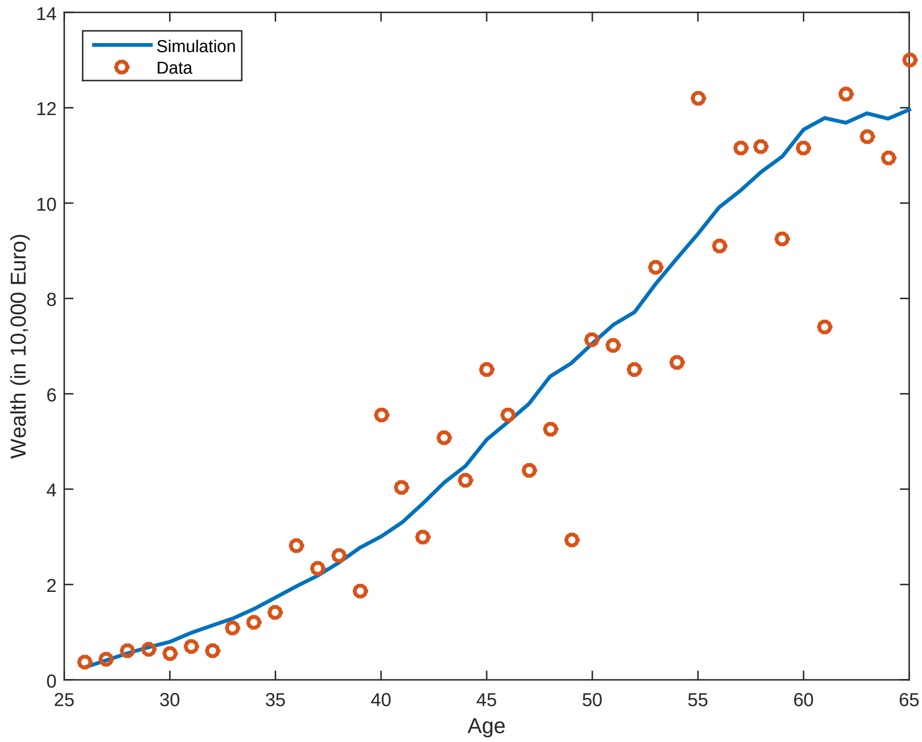

Figure 6: Median wealth profiles of households: data and simulation.
Source: Authors' calculations based on the GSOEP (2012).

In general, the discount factor is tightly estimated whereas the standard error

[15]For instance, Cagetti (2003) estimates $\rho > 2$ by targeting the median wealth of households, Gourinchas and Parker (2002) find $\rho < 2$ by targeting the mean consumption of households, Chetty (2006), using the effects of wage changes on labor supply, finds that $\rho < 2$.

of the coefficient of relative risk aversion is large for subgroups samples. For this reason, we set the coefficient of relative risk aversion for each subgroup to be the same for the entire sample, and estimate the discount factor by targeting the median wealth profiles. In Appendix E, we do a robustness check where we choose a range of coefficient of relative risk aversion and estimate the discount factor to target the median wealth profiles.

Figure 6 shows that we match the median wealth profile of households reasonably well. The presence of labor income uncertainty, as we show in Appendix D, is what allows us to identify the coefficient of relative risk aversion and the discount factor separately.

The calibration of the wealth and income distribution at the beginning of the life cycle, the mortality rates and the interest rate are shown in Appendix F.2 and F.3. For the main results, we set the borrowing constraint $\underline{a} = 0$ and the bequest motive parameter $\alpha = 0$. However, our results are not sensitive to reasonable choices of the borrowing constraint and the bequest motive. Following Fehr et al. (2011), we use a gross replacement rate of 48 percent for pension incomes.

4 Results

In this section, we quantitatively evaluate the effect of progressive taxation on precautionary saving over the life cycle. Throughout, we compare a simulated economy under the stylized German progressive tax and transfer schedule with one under a revenue-neutral flat tax schedule. As in the three-period model, we control for the total tax revenue on the economy and focus on the quantitative effect of progressivity on saving. First, we study how progressive taxation affects the distribution and accumulation of wealth over the life cycle. Second, we investigate whether progressive taxation provides additional insurance or crowds out households' self-insurance. In particular, we calculate the partial insurance coefficients of permanent and transitory shocks over the life cycle. Finally, we present the welfare implication of the current progressive taxation in Germany. We present our results for the entire sample and for subgroups defined by household characteristics.

4.1 Progressive Taxation and Precautionary Savings

Our benchmark here is a model with a flat tax rate comparable to the German progressive tax schedule. Concretely, we do a Monte Carlo simulation of the income process under the parameter estimates reported in the previous section and calculate the average total tax revenue from the economy. We then take the average of the tax revenues from each household as the flat tax rate. Our estimated comparable flat tax rate is 25%.

The upper left graph in Figure 7 displays the average tax rate at each age over the life cycle under the two tax schemes. Progressive taxation essentially reallocates the tax burden from the young and the old to their middle ages. Again, as long as the present discounted value of after-government income is fixed, the degree of progressivity would not change the life cycle profiles of consumption and saving on average if there is no uncertainty. It is precisely through the presence of uncertainty that progressive taxation plays a role. The upper right graph shows that the median household has higher income under progressive taxation than under flat taxation as pre-government income of this household is rather low (see Figure 5).

The left graph in the second row in Figure 7 shows that there is less wealth accumulation under progressive taxation over the life cycle. On average, the median household would hold 24.6% less wealth. This is not surprising as progressive taxation reduces after-government income uncertainty and obviates the need for a wealth buffer as big as under flat taxation. However, this does not mean the precautionary *motive* is diminished under progressive taxation. Two forces are at work

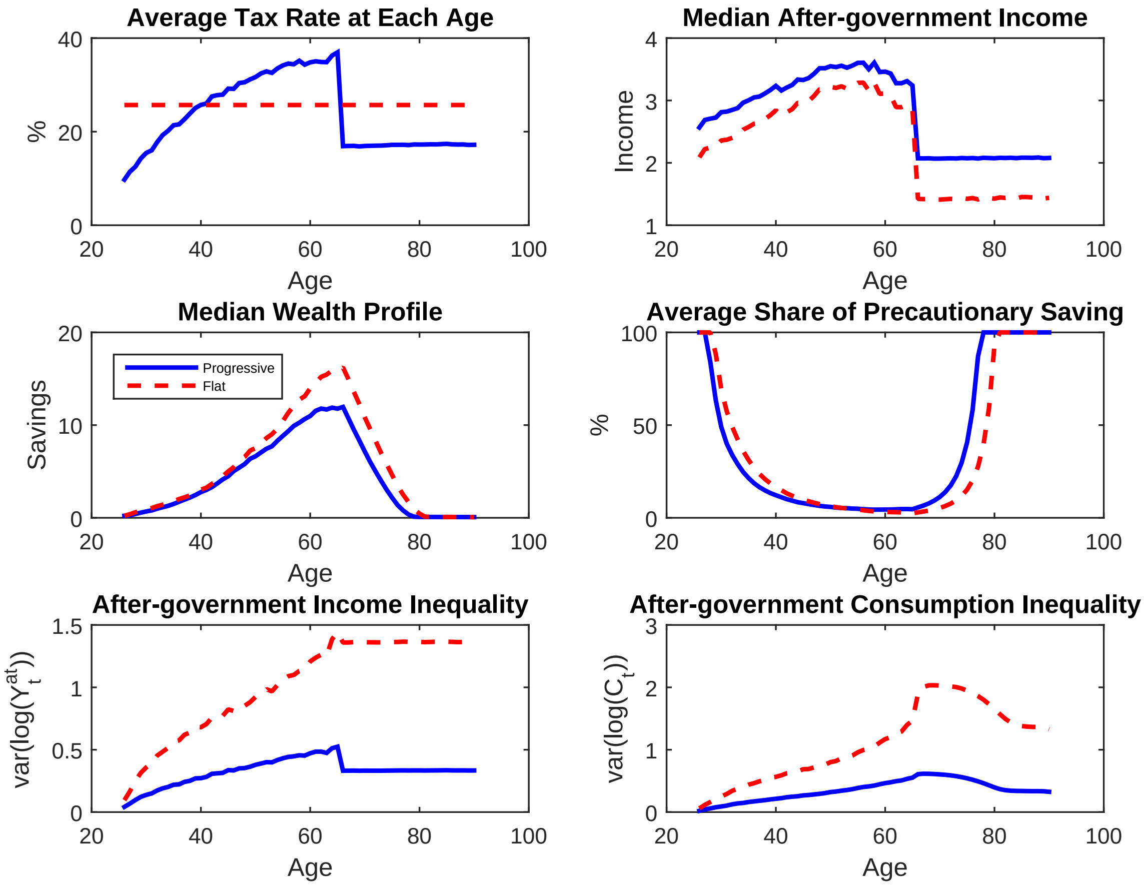

Figure 7: Effect of Progressive Taxation.
Note: The unit of levels is 10,000 Euro.
Source: Own simulation.

here: reduced after-government income uncertainty leads to reduced precautionary motive given a fixed wealth level, reduced wealth accumulation, on the other hand, intensifies precautionary motive given a fixed degree of uncertainty. In fact, as the right graph in the second row shows, the average share of precautionary saving in total saving at each age is not quantitatively different under two tax schemes.

After-government income inequality and after-government consumption inequality are both considerably smaller under progressive taxation, as shown in the bottom

Table 1: Average Share of Savings Crowded Out by Progressive Taxation

	Pre-government Income	Wealth	Reduction in Savings.
Total	4.453	3.900	24.6%
Employees	4.417	3.300	37.7%
Self-Employed	5.187	11.000	-11.0%
College graduates	6.012	7.850	19.1%
Apprenticeship	4.117	2.871	48.5%
Low educated	3.561	1.617	60.0%
Blue collar	3.620	1.950	27.9%
White collar	4.840	3.792	33.9%
Civil servant	5.123	7.584	22.4%
Married with children	5.042	6.558	24.9%
Married without children	5.020	7.584	44.8%
Single	3.391	1.625	26.7%

Notes: The first two columns display the median income and wealth in the data among various subgroups. Unit is 10,000 Euro. The last column shows the average reduction in savings over the life cycle for a household with median wealth.
Source: Own simulation.

two graphs in Figure 7. As a result, the distribution of consumption becomes tighter for each cohort under progressive taxation.

Importantly, the effect of progressive taxation on savings differs across the income and wealth distribution of households. For each subgroup of the population, we calculate the average savings crowded out by progressive taxation. Average reduction in savings would depend on each subgroup's income growth, income risk profile, and preferences. For instance, self-employed households tend to accumulate a larger wealth over the life cycle than other groups, indicating that they might be more patient. Progressive taxation would actually discourage their wealth accumulation because the saving motive for consumption smoothing outweighs the effect of reduction in uncertainty.

4.2 Partial Insurance of Permanent and Transitory Shocks

An important measure of consumption insurance against idiosyncratic labor income shocks in the literature is the partial insurance coefficients of permanent and transitory shocks (see Blundell et al. (2008b), Kaplan and Violante (2010), for instance). The idea is to measure how much income shocks (not) translate into consumption movements. In this section, we use our calibrated model to assess the effect of progressive taxation on consumption insurance.

As in Kaplan and Violante (2010), we define the partial insurance coefficients of permanent and transitory shocks as

$$\phi_t^{\psi} = 1 - \frac{cov(\Delta \log C_{it}, \psi_{it})}{var(\psi_{it})} \tag{15}$$

$$\phi_t^{\xi} = 1 - \frac{cov(\Delta \log C_{it}, \xi_{it})}{var(\xi_{it})} \tag{16}$$

When $\phi_t = 1$, there is perfect insurance; when $\phi_t < 1$, there is only partial insurance. The benefit of a structural model is that it allows us to directly calculate the insurance coefficients by simulation.

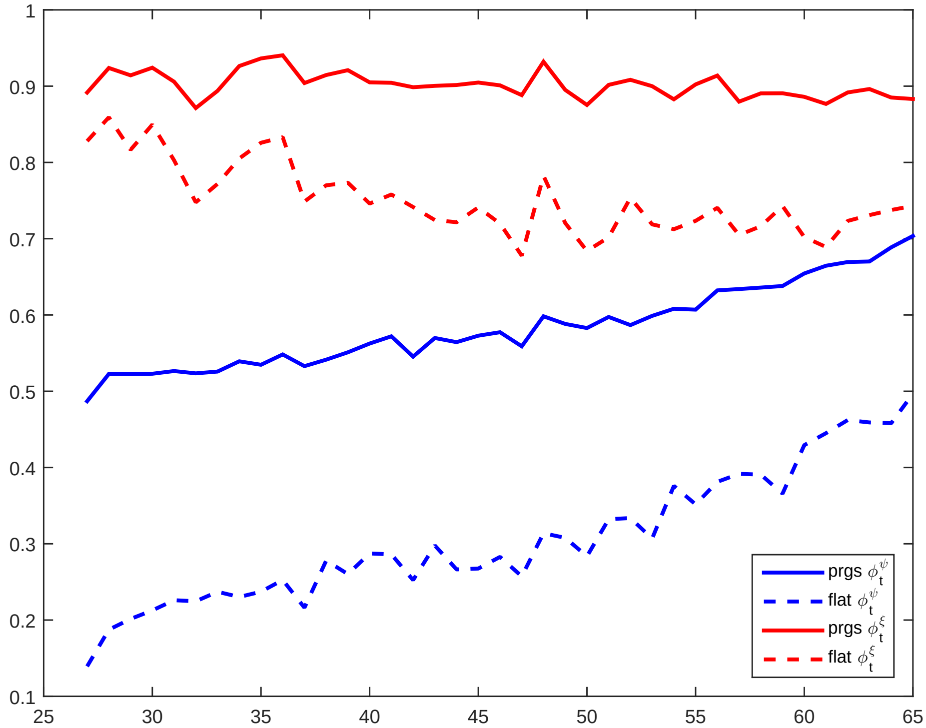

Figure 8: Partial Insurance Coefficients of Permanent and Transitory Shocks.
Source: Own simulation.

Table 2: Insurance Effect of Progressive Taxation.

	Progressive		Flat	
	$\bar{\phi}^{\psi}$	$\bar{\phi}^{\xi}$	$\bar{\phi}^{\psi}$	$\bar{\phi}^{\xi}$
Total	0.589	0.902	0.305	0.745
Employees	0.576	0.906	0.300	0.761
Self-Employed	0.716	0.893	0.413	0.662
College graduates	0.573	0.836	0.298	0.642
Apprenticeship	0.548	0.907	0.291	0.791
Low educated	0.630	0.919	0.326	0.789
Blue collar	0.550	0.895	0.267	0.764
White collar	0.548	0.880	0.266	0.724
Civil servant	0.614	0.943	0.355	0.818
Married with children	0.581	0.942	0.322	0.828
Married without children	0.451	0.886	0.255	0.846
Single	0.619	0.924	0.325	0.752

Notes: The insurance coefficients are calculated as the average over ages 26-65 for each subgroup.
Source: Own calculations.

Figure (8) presents the partial insurance coefficients of permanent and transitory shocks over the life cycle under the two tax schemes[16]. Apparently, there is more insurance against transitory as well as permanent shocks under progressive taxation. However, this is not obvious because under flat taxation there is more wealth accumulation. Indeed, by crowding out part of savings of households, progressive taxation reduces self insurance; but it reduces after-government income uncertainty as well and thus increases social insurance more than enough for the reduction in self-insurance. Interestingly, the insurance coefficients under flat taxation catch up

[16]One should be careful in interpreting our results here. The partial insurance in Figure (8) is the insurance against shocks to pre-government income, whereas it is the insurance against shocks to after-government income in most of the literature (Blundell et al. (2008b),Kaplan and Violante (2010)). The distinction vanishes under flat taxation, because variances of shocks to pre- and after-government income are the same. Our insurance coefficients associated with flat taxation are in line with the numbers in the previous literature.

but never exceed those under progressive taxation. This is due to the limited life span which, in turn, limits wealth accumulation and hence the degree of self-insurance.

Table 2 compares the average insurance coefficients for different subgroups between the two tax schemes. For every subgroup, progressive taxation provides more insurance against income shocks. In particular, going from flat taxation to progressive taxation, the insurance against permanent shocks lifts from approximately 30% to 60%, while the insurance against transitory shocks lifts from about 70% to 90% on average.

4.3 Welfare Effect of Progressive Taxation

We measure welfare as the present discounted value of certain income that yields the same expected utility as when there is income uncertainty. To be specific, we calculate the present discounted value Y_{PDV} such that the optimal consumption stream $\{\tilde{C}_{it}\}$ chosen with initial wealth Y_{PDV} and no future labor income uncertainty satisfies

$$\sum_{t=t_0}^{T+t_0} u_t(\tilde{C}_{it}) = E_{t_0}\left[\sum_{t=t_0}^{T+t_0} u_t(C_{it})\right].$$

Table 3 shows that the median household is indifferent between the revenue neutral flat tax under uncertainty and 631 thousand Euro which he receives with certainty; In contrast, the median household is indifferent between the revenue neutral progressive tax under uncertainty and 734 thousand Euro which he receives with certainty. Thus, the household has to be compensated with 103,000 Euro or 14% to choose the revenue neutral flat tax under uncertainty. The results for subgroups reveal considerable heterogeneity in welfare gains (losses) under progressive taxation. Consistent with a principle implied by vertical equity, i.e. that those who are more able to pay taxes should contribute with higher rates than those who are not, households with low income gain most from progressive taxation. Most households have welfare gain under progressive taxation which is not surprising, however, the magnitude of the gains and its variation across subgroups underscore the need for understanding the welfare implication on various groups of households when studying progressive taxation and designing reform proposals.

Table 3: Equivalent Income Under Two Tax Schemes.

	Progressive	Flat	Difference
Total	73.4	63.1	14.0%
Employees	74.6	64.7	13.2%
Self-Employed	86.1	78.8	8.5%
College graduates	101.8	102.6	-0.1%
Apprenticeship	77.1	68.8	10.8%
Low educated	56.0	41.1	26.6%
Blue collar	68.3	57.1	16.5%
White collar	83.3	76.6	8.1%
Civil servant	72.8	62.3	14.4%
Married with children	74.2	65.5	11.8%
Married without children	92.2	90.5	1.8%
Single	65.4	53.8	17.8%

Notes: Unit of income is 10,000 Euro.
Source: Own calculations.

5 Conclusion

This paper contributes to the understanding of the role of progressive taxation in precautionary saving. We estimate idiosyncratic labor income risk profiles over the life cycle for heterogenous household groups. Using an incomplete-markets life cycle model with estimated preference parameters, we show that progressive taxation, compared to a revenue-neutral flat taxation, reduces the average savings by 24.6%

for a household with median wealth. In our simulated economy under progressive taxation, 60% of permanent shocks and 30% of transitory shocks to pre-government labor income are insured against; In contrast, only 30% of permanent shocks and 70% of transitory shocks are insured against in an economy with a revenue-neutral flat taxation. There are sizeable welfare gains on average with progressive taxation but considerable heterogeneity among different subgroups.

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A Effect of Progressive Taxation on After-Government Income Uncertainty

The following formalization completes the arguments in the main analysis. A broader treatise of the fact that redistributive taxation helps to insure against individual risk is for example provided in Mirrlees (1974); Varian (1980).

After rewriting the tax function as $TX(Y_t) = \tau(Y_t)Y_t$, where $\tau : \mathbf{R}_+ \mapsto \mathbf{R}$ is the average tax rate function, we assume for ease of exposition that $\tau(Y)$ is continuous and piece-wise differentiable and that the corresponding marginal tax rate $\frac{d[Y\tau(Y)]}{dY} = \tau(Y)+Y\tau'(Y)$ is between $[0, 1)$. The immediate implication is that the tax function is non-decreasing. This assumption is rather weak. In particular, progressive taxation where the marginal tax rate is positive and increasing satisfies this assumption.

It is straight forward to show that (log) pre-government income can be expressed as

$$y_{it} - y_{it-1} = \epsilon_{it} \tag{17}$$

where ϵ_{it} is the uninsurable idiosyncratic component. We can think of after-government income as a new income process $\{X_t\}$, where $X_t = (1 - \tau(Y_t))Y_t$. Then it follows that log after-government income process is different from log gross income process only in their stochastic terms

$$x_{it} = x_{it-1} + f_{Y_{it-1}}(\epsilon_{it}) + \epsilon_{it} \tag{18}$$

where $x_{it} = \log X_{it}$, and $f_{Y_{it-1}}(\epsilon_{it})$ is the effect of taxation on the variation of after-government income. Under the assumption that marginal tax rate is between $[0, 1)$, it is easy to show that $0 < |f_{Y_{it-1}}(\epsilon_{it}) + \epsilon_{it}| < |\epsilon_{it}|$. Thus progressive taxation reduces the size of after-government income shocks. Similarly, one can show that progressive taxation reduces the conditional variance of after-government income shocks.

If we make further the assumption that the marginal tax rate is non-decreasing, that is, $\frac{d^2[Y\tau(Y)]}{dY^2} \geq 0$, we can show that expected human wealth is concave. Suppose, a household has permanent income P_t at the age t and could potentially have pre-government income Y_{t+s} at the age $t+s$. Then

$$Y_{t+s} = P_t \left(\prod_{w=1}^{s} \Gamma_{t+w} \Psi_{t+w} \right) \Xi_{t+s} = P_t \left(\prod_{w=1}^{s} \Gamma_{t+w} \right) \Upsilon_{t+s},$$

where $\Upsilon_{t+s} = \left(\prod_{w=1}^{s} \Psi_{t+w} \right) \Xi_{t+s}$ is a mean-zero cumulative shock. By the Jensen's inequality, we have

$$\begin{aligned} E[\tau(Y_{t+s})Y_{t+s}] &= \int \tau(Y_{t+s})Y_{t+s} d\Upsilon_{t+s} \\ &\geq \tau(\int Y_{t+s} d\Upsilon_{t+s}) \int Y_{t+s} d\Upsilon_{t+s} \\ &= \tau(E[Y_{t+s}])E[Y_{t+s}]. \end{aligned}$$

Hence,

$$\begin{aligned} E\left[(1-\tau(Y_{t+s}))Y_{t+s})\right] &= E[Y_{t+s}] - E[\tau(Y_{t+s})Y_{t+s}] \\ &\leq E[Y_{t+s}] - \tau(E[Y_{t+s}])E[Y_{t+s}] \\ &= (1-\tau(E[Y_{t+s}]))E[Y_{t+s}]. \end{aligned}$$

That is, expected after-government income at any future period would be concave in current permanent income. Since the human wealth is simply the sum of discounted future incomes,

$$H_t = Y_t + \frac{Y_{t+1}}{1+r} + \frac{Y_{t+2}}{(1+r)^2} + \cdots$$

It is straightforward that the expected human wealth is also concave in current permanent income.

B Numerical Solution to the Consumer's Problem

For ease of notation, we suppress the household index i. The consumer's optimization problem in our model is

$$\max_{C_t} E_{t_0}\left[\sum_{t=t_0}^{T+t_0} S_t \beta^{t-t_0} u(C_t)\right].$$

subject to

$$\begin{aligned}
A_t &= M_t - (1+\tau_C)C_t, \\
M_{t+1} &= A_t R + (1-\tau(Y_{t+1}))Y_{t+1}, \\
Y_{t+1} &= P_{t+1}\Xi_{t+1}, \\
P_{t+1} &= P_t \Gamma_{t+1} \Psi_{t+1},
\end{aligned}$$

where $R = (1 + r(1-\tau_A))$ is the gross interest factor.

There are two state variables in this problem, market wealth M_t and pre-government income Y_t. The only place where the level of permanent income plays a role is inside the tax function. Had there been no tax or a flat tax, we would reduce one state variable by normalization. However, the specialty of our problem is that the tax function is progressive, and hence the solution to consumption function crucially depends upon the level of permanent income.

The consumer's optimization problem can be solved recursively with the Euler equations for $t < T$

$$u'(C_t(M_t, P_t)) = R\beta \frac{S_{t+1}}{S_t} E_t[(\psi_{t+1}\Gamma_{t+1})^{-\rho} u'(C_{t+1}(M_{t+1}, P_{t+1}))], \tag{19}$$

where $C_t(M_t, P_t)$ represents the optimal consumption rule in period t and $C_T(M_T, P_T) = M_T$. To enhance speed and to ensure accuracy, we take several steps in numerically solving for $c_t(m_t, P_t)$. For each period, we specify the grid for the level of permanent income and construct the grid for market wealth at each level using the method of endogenous grid points (Carroll (2006)). The grid for permanent income is spaced such that there are more points closer to zero, since the tax schedule tends to be more progressive (hence highly nonlinear) at lower levels of income. The grid for assets is chosen such that there are more points closer to the borrowing constraint. We choose 8 points for the transitory shocks and 7 points for the permanent shocks. Cross-sectional distributions are obtained by simulation with 10,000 agents in each period.

C Method of Simulated Moments

The method of simulated moments was first introduced by McFadden (1989) and Pakes and Pollard (1989) in the estimation of discrete choice models. Lee and Ingram (1991) extended this method to a time-series setting and Duffie and Singleton (1993) to Markov models. Since the results of our paper rely on the distribution of income and wealth, we use an extension of the method of simulated moments to match households' median wealth (see Powell (1994)).

Let $\Theta = [\rho, \beta]$ be the set of parameters to be estimated in the second stage. Given estimated parameters in the first stage and $\theta \in \Theta$, we can simulate the model

Table 4: Variables and Parameters.

Parameter	Definition
β	time invariant discount factor
ρ	coefficient of relative risk aversion
$\underline{A}$	borrowing constraint
R	gross real interest rate
A_{t_0}	initial asset
Y_{t_0}	initial income

Variable	Definition
Y_t	pre-government income
M_t	market wealth
A_t	beginning-of-period asset
P_t	permanent income
S_t	unconditional probability of survival
Γ_t	deterministic growth factor of permanent income
Ξ_t	transitory shocks to gross income
Ψ_t	permanent shocks to gross income
y_t	log gross income
g_t	deterministic growth rate of permanent income
p_t	log permanent income
ξ_t	transitory shock to gross income growth rate
ψ_t	permanent shock to gross income growth rate
σ_{ξ_t}	standard deviation of transitory shocks
σ_{ψ_t}	standard deviation of permanent shocks

for a large number of agents. Denoting the simulated wealth distribution of agents at time t by $F_t^m(\theta)$ and the empirical wealth distribution at time t by $\hat{F}_t$, we can compute the distance of $F_t^m(\theta)$ and $\hat{F}_t$. The second stage parameters are estimated so that the distance between the simulated and the empirical wealth distribution is the smallest. We define the distance as the difference between the πth quantile of the wealth distribution.

Let $m_{t,i}$ be market wealth of agent i at time t. If θ_0 were the true parameter values, the πth quantile of wealth distribution at time t would be $m_t(\theta_0)$, satisfying the moment condition

$$E\left[\pi - \mathbf{1}(m_{t,i} \leq m_t(\theta_0))|t\right] = 0, \tag{20}$$

where $\mathbf{1}$ is the indicator function. To estimate θ, we solve the loss function

$$\min_{\theta} E\left[(m_{t,i} - m_t(\theta))(\pi - \mathbf{1}(m_{t,i} \leq m_t(\theta)))|t\right]. \tag{21}$$

The above moment condition (20) is conditional on time t. We care not only about the wealth distribution at a particular point in time but also the accumulation of wealth over time. Aggregating the moment conditions over time, we obtain the loss function[17]

$$\min_{\theta} E\left[(m_{t,i} - m_t(\theta))(\pi - \mathbf{1}(m_{t,i} \leq m_t(\theta)))q(t)\right], \tag{22}$$

where $q(t)$ is the weighting function used to account for the evolution of wealth over time. An efficient choice would be $q(t) = f(m_t(\theta_0))$, the density of the distribution of wealth at the πth quantile at time t, under which the estimator $\hat{\theta}$ has a distribution

$$\sqrt{N}(\hat{\theta} - \theta_0) \xrightarrow{d} N(0, \Omega) \tag{23}$$

[17] We use a minimization procedure that does not rely on the existence of the gradient (simplex).

and

$$\Omega = \pi(1-\pi)\left(E\left[f^2(m_t(\theta_0))\frac{\partial m_t(\theta_0)}{\partial\theta}\frac{\partial m_t(\theta_0)}{\partial\theta'}\right]\right)^{-1}. \tag{24}$$

We denote by n_j the number of observations in at age t. The sample analog of the aggregate loss function is

$$\min_\theta \sum_{t=1}^{40}\sum_{i=1}^{n_j}(m_{t,i} - m_t(\theta))(\pi - \mathbf{1}(m_{t,i} \leq m_t(\theta)))q_t \tag{25}$$

We first set $q(t) = 1$ and obtain a consistent estimate $\hat{\theta}_1$ of θ_0, and then choose the empirical density at $m_t(\hat{\theta}_0)$ of the distribution of wealth at the πth quantile of age t, $\hat{f}(m_t(\theta_0)|t)$, to be the weight q_t. The empirical density function $\hat{f}$ is estimated nonparametrically with a Gaussian kernel.

D Identification of the Model

In this section, we discuss how wealth data identify the parameters in the model. This is done for the purpose of exposition only. A rigorous proof is beyond the scope of this paper. In fact, because there is not a closed-form analytical solution to models with labor income uncertainty[18], there has not been any formal proof of identification in the literature.

In our model, the coefficient of relative risk aversion (ρ) and the discount factor (β) are estimated by matching simulated and empirical median wealth profiles over the life cycle. As argued below, the empirical profile of wealth accumulation identifies consumption growth over the life cycle, and the difference in consumption growth between young and old households then identifies the coefficient of relative

[18] A recent exception is Heathcote et al. (2009), where wealth is a redundant state variable in their model. Tractability of the model and identification of parameters there are thus obtained.

risk aversion and the discount factor. Consumption growth can be rewritten using the budget constraint as

$$\frac{C_{t+1}}{C_t} = \frac{M_{t+1} - A_{t+1}}{M_t - A_t}. \tag{26}$$

Note that A_t determines M_{t+1} via (19). A sequence of market wealth $\{M_t\}_{t=t_0+1}^{t_0+T^{work}}$ is therefore determined by the empirical profile of $\{A_t\}_{t=t_0}^{t_0+T^{work}}$. As a result, consumption growth is identified by the empirical profile of wealth through (26). Recall that the Euler equation (19) implicitly determines expected consumption growth. Rewriting it in the context of CRRA utility function, we obtain

$$C_t = \left(R\beta\frac{S_{t+1}}{S_t}\right)^{-\frac{1}{\rho}} \Gamma_{t+1} E_t[(\psi_{t+1}C_{t+1})^{-\rho}]^{-\frac{1}{\rho}}. \tag{27}$$

If there was no labor income uncertainty, transitory and permanent shocks as well as the expectation sign would disappear in the Euler equation. Consequently,

$$\frac{C_{t+1}}{C_t} = \frac{\left(R\beta\frac{S_{t+1}}{S_t}\right)^{\frac{1}{\rho}}}{\Gamma_{t+1}}, \tag{28}$$

in which case ρ and β are not identified because any combination of $(\rho,\ \beta)$ that satisfies $\beta^{\frac{1}{\rho}} = k$, where k is a constant, would suffice for the desired growth rate of consumption. However, this is not the case when there is labor income uncertainty. When households are old, their consumption is very close to what it would be when there was no uncertainty because they have accumulated a lot of assets to insure themselves against idiosyncratic shocks. Consumption growth for the old is primarily governed by the factor $\frac{\left(R\beta\frac{S_{t+1}}{S_t}\right)^{\frac{1}{\rho}}}{\Gamma_{t+1}}$. In contrast, when agents are young, wealth level is low and uncertainty plays a big role in determining households' consumption growth. As is indicated in equation (27), not only does consumption growth depend on the term $\frac{\left(R\beta\frac{S_{t+1}}{S_t}\right)^{\frac{1}{\rho}}}{\Gamma_{t+1}}$, but it also depends on the curvature of marginal utility, which is governed solely by ρ. Thus the difference in consumption growth between young and old will identify both the coefficient of relative risk aversion and the discount factor.

E Robustness of Parameter Choices

In this section, we investigate the robustness of our results to various preference parameter choices. As is mentioned in Appendix D, identification of the preferences is achieved by the slope and curvature of the wealth profile of the median household. In light of the noisiness in the data, however, our estimate of the risk aversion is subject to large standard errors in some occasions. For this reason, we choose various values of risk aversion and estimate the discount factor using the method of simulated moments. Table 5 displays the estimates.

Table 5: Estimates of Discount Factor.

	$\rho = 0.6529$ (preferred)	$\rho = 0.5$	$\rho = 1$	$\rho = 2$	$\rho = 3$
Total	0.9633	0.9622	0.9622	0.9627	0.9608
Employees	0.9630	0.9619	0.9635	0.9621	0.9545
Self-Employed	0.9767	0.9730	0.9839	1.0025	1.0132
College graduates	0.9705	0.9667	0.9722	0.9866	0.9893
Apprenticeship	0.9616	0.9611	0.9618	0.9565	0.9523
Low educated	0.9600	0.9599	0.9606	0.9600	0.9593
Blue collar	0.9600	0.9607	0.9594	0.9539	0.9443
White collar	0.9632	0.9624	0.9629	0.9604	0.9555
Civil servant	0.9650	0.9635	0.9675	0.9720	0.9744
Married with children	0.9676	0.9659	0.9720	0.9793	0.9826
Married without children	0.9565	0.9577	0.9542	0.9428	0.9281
Single	0.9658	0.9633	0.9700	0.9793	0.9865

Source: Own calculations.

F Data Description

F.1 Labor Income and Wealth

Our measure of labor income, available from 1984 to 2012, combines annual household pre-government labor income that this household received in the calendar year previous to the survey year. More specifically, labor income is the sum of income from primary job, secondary job, self-employment, service pay, 13th month pay, 14th month pay, Christmas bonus pay, holiday bonus pay, miscellaneous bonus pay, and profit-sharing income. Household heads with non-zero pension and private transfer income are excluded from the sample. Moreover, we exclude household heads that are retired, in education (including serving an apprenticeship, working as a trainee or intern) or in military service.

We use wealth data that are available in the 2002, 2007 and 2012 waves. The GSOEP questionnaire for these two waves included a special module that collected information about private wealth. The surveys asked about the market value of personally owned real estate (owner-occupied housing, other property, mortgage debt), financial assets, tangible assets, private life and pension insurance, consumer credit, and private business equity (net market value; own share in case of a business partnership). The wealth balance sheets referred to the personal level, so in the case of jointly owned assets, the survey explicitly asked about each person's individually owned shares. The variables on labor income and wealth are aggregated to the household level and deflated to 2007 prices using the consumer price index provided by the Federal Statistical Office.

F.2 Initial Values

To initialize our model for simulation, we compute the wealth to income ratio distribution of households as follows. We take the wealth to income ratio data of households between ages 20 and 25 and trim the top 2% and the bottom 2%. Assuming that it follows a shifted log-normal distribution, we take the logarithm of the ratios and compute its mean and variance. With the shift, mean and variance, we discretize the distribution equiprobably. A discretization of the initial income distribution is obtained in a similar manner. We assume that these two distributions are independent.

F.3 Mortality Risk and Interest Rates

Households are assumed to live more than 65 and less than 91 years. For the probability to stay alive after retirement, we rely on the observations given in the life tables in the Human Mortality Database (HMD henceforth) for Germany, available at www.mortality.org. The life tables include survival probabilities and life expectancies that vary by age and are available for the years 1991 - 2012. The HMD is provided by the University of California, Berkeley (USA) and Max Planck Institute for Demographic Research (Germany). Our data is affected by the relative size of the female and male populations at a given age and time. Therefore, we do not use the probabilities for women only (as done in Hubbard et al. (1995); Cagetti (2003)) but calculate first the age effects of the conditional probabilities of survival from 1991 to 2012 and then the probability to survive $t - t_0$ periods for each year from age 65 on.

We take annual averages of domestic mid- and long-term bonds yields as provided by the Deutsche Bundesbank to estimate the gross real interest rate. Over the sample period from 1984 to 2012 the yearly average real interest rate is 5.939 with a standard error of 2.735.

F.4 Estimation of the Income Growth Rate

To remove the common trend of observed household pre-government labor income, we conduct a fixed-effects regression of the log of this variable on a third order polynomial of age, dummies indicating the highest level of education attained[19], dummies indicating the occupational status[20] attained and two-way interactions between these categories and the age polynomial.

We apply different strategies to separate age, time and cohort effects. For instance, we follow Deaton and Paxson (1994) and generate a set of $S-2$ year dummies defined as $d_s^* = d_s - [(s-2)d_1 + (s-1)d_2]$, from survey year $s = 3, \ldots, S$. Here d_s is a binary indicator for each year. This implies the restriction that the year dummies add to zero and are orthogonal to a linear trend. Recall, that we need to impose restrictions because of the identity $a = t - c$, where c denotes year of birth. If cohort effects are not affecting slopes, the elimination of the fixed effects removes also cohort shifters (French (2005)). The results remain similar if we drop the cohort dummies. We cluster standard errors at the cohort level.

Moreover, we include household size indicators d_h for the number of persons $h = 1, .., 5$ in a household, where $d_{h=6}$ represents six or more persons. We also control for the total annual number of hours worked by all household members.

The average predicted income growth rates at each age is the deterministic growth rate of a household with the size of three persons (except for singles and married without children), and with average working hours. We restrict business cycle effects to be zero. We use these growth rates to calibrate our life cycle model. We then work with residuals from the regression as a measure of the idiosyncratic component of pre-government income (see below in this section).

[19] There are five level of educational attainment: (i) a degree from an university, (ii) having served as an apprentice, (iii) having attained a degree that allows to study at an university, (iv) a degrees from other secondary schools, (v) not having attained any qualification. The base category are individuals who hold a degree from an university. This set of binary variables is mutually exclusive: For example, if an individual has served as an apprentice and a degree from other secondary schools but holds no degree from university, a binary variable for apprenticeship is one and all other education dummies are zero.

[20] There are two mutually exclusive occupational categories: (i) self-employment, (ii) employment. The base category are individuals in category (i).

We separately estimate these growth rates for groups in our sample that differ with respect to education, occupation, employment, and marital status. Figure 9 shows the average predicted income levels calculated using the estimated growth rates for each subgroup. This figure shows how pre-government income would evolve over the life cycle for the same household head who receives 20,000[21] Euro of labor income at age 25 in different groups.

The top left graph shows strong differences by educational attainment. University graduates have a much steeper income profile than all other groups. This is not surprising, still the reader should recall that we estimate growth rates based on household and not personal labor income. As is well known, university graduates constitute often a household with other university graduates. This makes the household income profile even steeper compared to other groups. For example, apprentices' household income has only risen by about 10,000 Euro when household heads turn 55 with a modest decline thereafter. We offer two explanations for this decline: First, less educated household heads tend to work in more physically demanding occupations (see the income profile for blue collar workers below). For this reason they might work fewer hours (and accept lower real wages) towards retirement. Second, there have been financial incentives to do part-time work for older employees fixing nominal hourly wages.[22] The simulated pre-government labor income profile of household heads whose highest educational attainment is apprenticeship does not differ much from that of persons indicating no education. This is not surprising as we exclude household heads earning less than 9,600 Euro per year from the analysis.

The top right graph shows the simulated pre-government labor income profiles for

[21] This number is not entirely arbitrary. In fact, comparing the estimates to the evidence provided by the Federal Statistical Office (Fachserie 16) shows that the pre-government labor income profiles are estimated quite accurately using 20,000 to 25,000 Euro as initial income.

[22] See law for part-time work for older employees (Altersteilzeitgesetz, AltTZG).

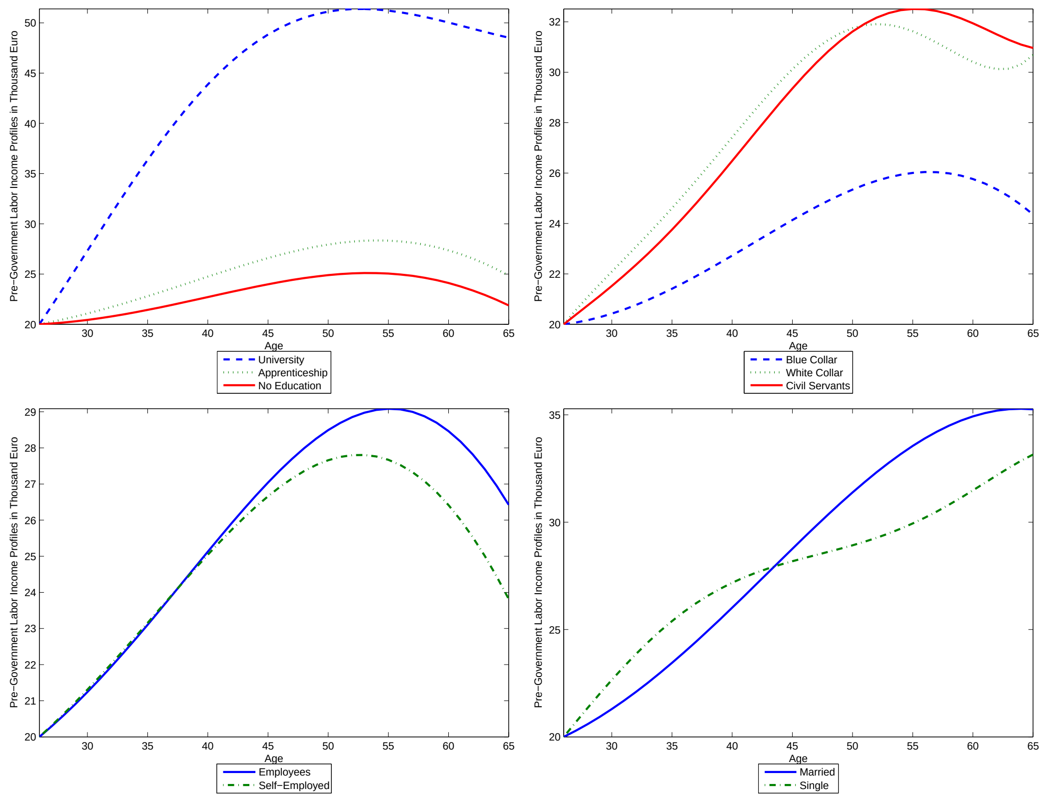

Figure 9: Average of predicted income levels at each age for various subgroups with initial income 20,000 Euro.
Source: Authors' calculations based on the GSOEP (1984-2012).

different occupational groups. Civil servants profiles rise increasingly quickly, slowing down shortly before age 50. Their income peaks age 55 and declines somewhat towards retirement. This decline seems to be caused by the law incentivizing part-time work for civil servants older than 55. For white collar workers who receive the highest level of pre-government income up to age 50, there is a modest decline towards retirement. Blue collar workers, in contrast, have scaled down profiles with a slight decline towards the end of working life. Again, we argue that this is due to either early retirement schemes or reduction in hourly wages because of physically demanding work.

The bottom left graph shows profiles for employees, that is not self-employed household heads, in contrast to self-employed. Their profiles are very similar up to age 50 when incomes of self-employed decline substantially. One explanation of this pattern is that self-employed put more of their income in their business and receive more income from capital income towards the end of working life.

The bottom right graph displays income profiles of persons who are living in single households and married couples. As with self-employed, household heads are unlikely to stay single during their entire life. However, in our exercise we concatenate observations of persons observed at each age to learn what would be the labor income profile if a household head would indeed not change marital status. Singles have more income before age 45, presumably, because they are able to provide more labor supply as they do not need to do unpaid housework. Or conversely, the fact that low productive persons marry early can explain the pattern observed.

F.5 Estimation of the Income Risks

In first differences the income process (9) is

$$\Delta y_t = \psi_t + \xi_t - \xi_{t-1},$$

where

$$\xi_t - \xi_{t-1} = \varphi(\xi_{t-1} - \xi_{t-2}) + \varepsilon_t + (\theta - 1)\varepsilon_{t-1} - \theta\varepsilon_{t-2},$$

and recursive substitution yields

$$\xi_t - \xi_{t-1} = \varphi^2(\varphi\xi_{t-3} + \varepsilon_{t-2} + \theta\varepsilon_{t-3} - \xi_{t-3}) + \varphi\varepsilon_{t-1} + \varphi(\theta-1)\varepsilon_{t-2} - \varphi\theta\varepsilon_{t-3} + \varepsilon_t + (\theta-1)\varepsilon_{t-1} - \theta\varepsilon_{t-2}.$$

The theoretical moments are given in equations (10) to (12) where

$$\sigma^2_{\Delta\xi,25} = \varphi^2\sigma^2_{\Delta\xi,24} + \sigma^2_{\varepsilon,25} + \sigma^2_{\varepsilon,25}[(\theta-1)^2 + \theta^2 + 2\varphi(\theta-1) - 2\varphi\theta(\varphi+\theta-1)],$$

$$\sigma^2_{\Delta\xi,26} = \varphi^2\sigma^2_{\xi,25} + \sigma^2_{\varepsilon,26} + \sigma^2_{\varepsilon,25}(\theta-1)^2 + \sigma^2_{\varepsilon,25}\theta^2 + 2\varphi(\theta-1)\sigma^2_{\varepsilon,25} - 2\varphi\theta(\varphi+\theta-1)\sigma^2_{\varepsilon,25},$$

$$\sigma^2_{\Delta\xi,t} = \varphi^2\sigma^2_{\Delta\xi,t-1} + \sigma^2_{\varepsilon,t} + \sigma^2_{\varepsilon,t-1}(\theta-1)^2 + \sigma^2_{\varepsilon,t-2}\theta^2 + 2\varphi(\theta-1)\sigma^2_{\varepsilon,t-1} - 2\theta\varphi(\varphi+\theta-1)\sigma^2_{\varepsilon,t-2}.$$

The empirical moments, taking into account that the data used in estimations are unbalanced[23], are calculated as

$$\hat{\Omega} = \frac{\Lambda}{N_{ta'}},$$

where Λ is the vectorized lower triangular part of the symmetric matrix $\sum_{i=1}^{N} \tilde{y}_i\tilde{y}_i'$ and $\tilde{y}_i = [\Delta y_{i2}, \Delta y_{i3}, \ldots, \Delta y_{iA}]$ and N is the total number of heads in the sample. $N_{ta'}$ is a vector with row dimension $A(A+1)/2$. N_{11} is the number of heads contributing toward estimation of the variance in period 1 ($a = 1, a = 1$), N_{12} is the number of heads contributing toward estimation of the first-order autocovariance between periods 1 and 2 ($a = 1, a = 2$), and so forth. If a head's income is missing, this head's contributions toward the variance at time 1 and all the sample autocovariances involving this period are restricted to zero.

The vector of the 81 model parameters Θ, are recovered by minimizing a squared distance function $[\Omega(\Theta) - \hat{\Omega}]'I[\Omega(\Theta) - \hat{\Omega}]$, where I is an identity matrix with the row

[23] We follow Hryshko (2012).

dimension $A(A+1)/2 = 406$.[24] Standard errors of the parameters are calculated as the square roots of the diagonal of

$$(\tilde{\Omega}'_\Theta \tilde{\Omega}_\Theta)^{-1} \tilde{\Omega}'_\Theta V \tilde{\Omega}_\Theta (\tilde{\Omega}'_\Theta \tilde{\Omega}_\Theta)^{-1},$$

where $\tilde{\Omega}_\theta = \frac{\partial}{\partial \theta}[\Omega(\hat{\theta}) - \hat{\Omega}]$, a vector with the row dimension $A(A+1)/2$, and the column dimension equal to the row dimension of the vector of estimated parameters; V is equal to $\sum_{i=1}^{N} (\hat{\Omega}_i - \hat{\Omega})(\hat{\Omega}_i - \hat{\Omega})/N_V$, where $\hat{\Omega}_i$ is the vectorized lower triangular part of the symmetric matrix $\tilde{y}_i \tilde{y}'_i$, and the klth element of N_V is calculated as $N_V^{kl} = N_{ta'}^k N_{ta'}^l$, where $N_{ta'}^k$ is the kth element of $N_{ta'}$.

Figure 10 shows the average empirical autocovariance function and the theoretical autocovariance function with the estimated parameters. It is obvious that the autocovariance function is significant only from order 0 to order 2 and that the contribution of the transitory component toward the autocovariance function tails off rather quickly. The estimated parameters along with their standard errors in parentheses are shown in Tables 6 to 9. Note that all negative point estimates in these tables are not statistically different from zero.

Table 6 shows our estimates for three levels of education: Both permanent and transitory variances are presented for household heads who are university graduates, those who have served an apprenticeship and no higher professional training, and those who do not have indicated having any education. A striking fact from this table is that university graduates face large permanent shocks which reduce rapidly up to their mid 40s. They stay on a rather low level but increase towards retirement age modestly. In contrast, transitory shocks remain quite constant and relatively small over the life cycle.[25] Apprenticeship trained household heads face larger permanent

[24] We use a Quasi-Newton method for the minimization procedure.

[25] This are in line with the findings in Blundell et al. (2014) who find that after taking out calendar

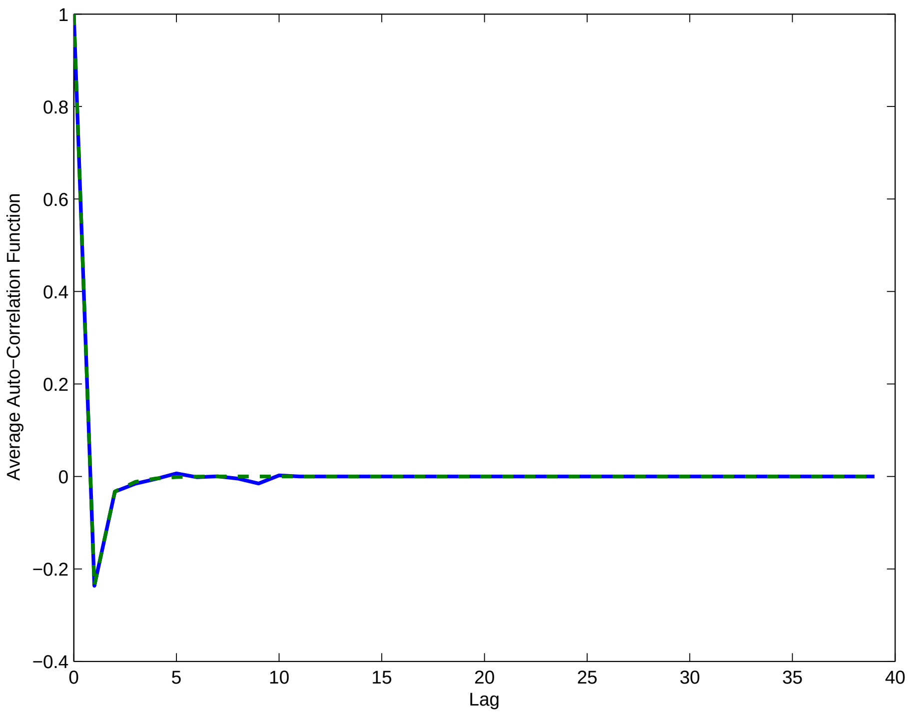

Figure 10: Average Empirical Autocovariance Function with Lags of Order 10 or Higher Restricted to Zero and the Theoretical Autocovariance Function with the Estimated Parameters.
Source: Authors' calculations based on the GSOEP (1984-2012).

than transitory variances both of which decline with age but rise again at a relatively slow pace after age 45. Not having attained education means facing quite large transitory shocks which are increasing towards retirement age. However, permanent shocks start from a comparatively low level and then decline steadily. These findings seem intuitive, permanent shocks, e.g. promotions, permanently higher productivity or health risks are more likely to affect labor income of higher educated persons, while transitory shocks are relatively important for the less educated. Moreover,

time effects, the variance of transitory shocks exhibits a smooth and decreasing profile over the life cycle.

university graduates who might start a business in young years or move up within a firm are known to face large uncertainties. At young ages higher uncertainty is also documented for the other groups but at a much smaller level. Why does uncertainty rise at the end of working live? Shocks to health and thus productivity might increase at higher ages.

Table 7 displays the same estimates for two groups, namely self-employed and employees, as well as for the entire sample. As expected self-employed face large risks. In fact, permanent variances are about twice as high as transitory variances. They follow the known u-shape over the life cycle. As the fraction of self-employed is quite small, the total sample and the employees have similar risks over the life cycle. For employees transitory risks remain quite stable throughout, while permanent uncertainty is high in young years declining towards retirement.

Table 8 shows that the three occupational groups face all constant transitory and u-shaped permanent risks over the life cycle. While transitory uncertainty is roughly on the same level for all three groups, permanent uncertainty is highest for white collar workers at early ages, second highest for civil servants, and lowest for blue collar workers. Towards retirement blue collar and white collar workers end up with almost the same uncertainty. Civil servants, however, faces almost no uncertainty at all at higher ages.

Finally, Table 9 shows that for married household heads transitory uncertainty is on average relatively more important than permanent, while this pattern is on average reverse for singles. Interestingly, singles face less uncertainty at young ages. However, towards the end of working life, in particular the permanent uncertainty is higher for singles compared to married.

Table 6: Permanent and Transitory Variances over Age by Education.

Sample	University Graduates				Apprentices				Lower Education			
Age	$\hat{\sigma}^2_\psi$	s.e.	$\hat{\sigma}^2_\varepsilon$	s.e.	$\hat{\sigma}^2_\psi$	s.e.	$\hat{\sigma}^2_\varepsilon$	s.e.	$\hat{\sigma}^2_\psi$	s.e.	$\hat{\sigma}^2_\varepsilon$	s.e.
26	-	-	0.0484	0.0255	-	-	0.0250	0.0062	-	-	0.0490	0.0053
27	0.1677	0.0409	0.0080	0.0100	0.0590	0.0104	0.0282	0.0051	0.0733	0.0168	0.0662	0.0213
28	0.1389	0.0239	0.0351	0.0148	0.0583	0.0083	0.0377	0.0085	0.0208	0.0212	0.0768	0.0236
29	0.1348	0.0245	0.0433	0.0125	0.0506	0.0061	0.0228	0.0042	0.0344	0.0151	0.0605	0.0160
30	0.1015	0.0184	0.0231	0.0083	0.0482	0.0061	0.0307	0.0071	0.0541	0.0210	0.0474	0.0171
31	0.0733	0.0127	0.0238	0.0120	0.0484	0.0054	0.0263	0.0036	0.0260	0.0190	0.0585	0.0160
32	0.0922	0.0155	0.0306	0.0088	0.0512	0.0060	0.0280	0.0041	0.0192	0.0155	0.0651	0.0174
33	0.0756	0.0136	0.0139	0.0057	0.0323	0.0045	0.0296	0.0036	0.0413	0.0177	0.0416	0.0124
34	0.0541	0.0088	0.0229	0.0062	0.0279	0.0046	0.0313	0.0051	0.0150	0.0146	0.0577	0.0145
35	0.0404	0.0083	0.0319	0.0087	0.0378	0.0064	0.0339	0.0051	0.0220	0.0139	0.0568	0.0140
36	0.0606	0.0107	0.0391	0.0094	0.0330	0.0053	0.0250	0.0035	0.0235	0.0240	0.0673	0.0180
37	0.0229	0.0073	0.0336	0.0087	0.0323	0.0046	0.0281	0.0036	0.0172	0.0129	0.0517	0.0130
38	0.0408	0.0114	0.0381	0.0080	0.0326	0.0047	0.0297	0.0050	0.0009	0.0167	0.0687	0.0187
39	0.0242	0.0083	0.0307	0.0079	0.0250	0.0043	0.0283	0.0037	0.0038	0.0168	0.0765	0.0187
40	0.0288	0.0089	0.0234	0.0062	0.0240	0.0047	0.0315	0.0041	0.0193	0.0120	0.0460	0.0134
41	0.0221	0.0068	0.0256	0.0066	0.0196	0.0039	0.0270	0.0032	0.0004	0.0140	0.0620	0.0150
42	0.0215	0.0055	0.0237	0.0050	0.0310	0.0052	0.0216	0.0031	-0.0031	0.0161	0.0711	0.0197
43	0.0132	0.0054	0.0261	0.0057	0.0284	0.0044	0.0262	0.0033	0.0283	0.0137	0.0394	0.0113
44	0.0198	0.0060	0.0275	0.0063	0.0248	0.0042	0.0260	0.0037	0.0090	0.0128	0.0523	0.0132
45	0.0304	0.0068	0.0314	0.0076	0.0225	0.0036	0.0274	0.0039	-0.0078	0.0255	0.0768	0.0360
46	0.0082	0.0064	0.0450	0.0108	0.0267	0.0039	0.0271	0.0044	-0.0093	0.0171	0.0822	0.0213
47	0.0116	0.0135	0.0464	0.0140	0.0303	0.0047	0.0258	0.0042	-0.0094	0.0156	0.0712	0.0179
48	0.0160	0.0111	0.0349	0.0108	0.0309	0.0048	0.0221	0.0032	0.0078	0.0178	0.0720	0.0192
49	0.0159	0.0067	0.0272	0.0069	0.0289	0.0046	0.0235	0.0033	0.0249	0.0135	0.0503	0.0138
50	0.0147	0.0074	0.0247	0.0056	0.0307	0.0056	0.0233	0.0044	-0.0024	0.0174	0.0740	0.0203
51	0.0211	0.0066	0.0292	0.0077	0.0341	0.0047	0.0253	0.0041	0.0109	0.0151	0.0704	0.0183
52	0.0142	0.0054	0.0203	0.0044	0.0236	0.0045	0.0307	0.0047	0.0123	0.0170	0.0646	0.0160
53	0.0151	0.0084	0.0204	0.0057	0.0222	0.0060	0.0354	0.0079	0.0037	0.0149	0.0548	0.0167
54	0.0204	0.0094	0.0435	0.0136	0.0312	0.0087	0.0325	0.0050	0.0007	0.0257	0.0892	0.0327
55	0.0176	0.0072	0.0297	0.0072	0.0347	0.0067	0.0269	0.0048	0.0116	0.0170	0.0654	0.0204
56	0.0043	0.0076	0.0377	0.0103	0.0466	0.0071	0.0236	0.0041	0.0071	0.0196	0.0730	0.0201
57	0.0141	0.0091	0.0352	0.0081	0.0334	0.0057	0.0264	0.0046	0.0291	0.0156	0.0392	0.0141
58	0.0279	0.0102	0.0447	0.0159	0.0417	0.0067	0.0337	0.0062	0.0255	0.0153	0.0417	0.0137
59	0.0193	0.0107	0.0199	0.0095	0.0365	0.0071	0.0325	0.0054	0.0465	0.0205	0.0390	0.0150
60	0.0360	0.0121	0.0175	0.0051	0.0323	0.0096	0.0402	0.0096	0.0380	0.0229	0.0524	0.0207
61	0.0251	0.0068	0.0264	0.0073	0.0390	0.0111	0.0310	0.0073	-0.0744	0.0590	0.1713	0.0688
62	0.0084	0.0143	0.0547	0.0205	0.0470	0.0103	0.0278	0.0091	-0.0204	0.0424	0.1011	0.0550
63	0.0514	0.0131	0.0074	0.0070	0.0221	0.0161	0.0562	0.0157	-0.0364	0.0651	0.1151	0.0691
64	0.0743	0.0353	0.0268	0.0123	0.0670	0.0227	0.0596	0.0158	-0.0350	0.1216	0.1648	0.1378
65	-	-	0.0950	0.0296	-	-	0.1215	0.0396	-	-	0.0943	0.0463
Mean	0.0415	0.0117	0.0317	0.0099	0.0354	0.0067	0.0322	0.0063	0.0113	0.0230	0.0694	0.0248
AR(1)	1	-	0.0174	0.0392	1	-	0.1879	0.046	1	-	0.8183	0.0662
MA(1)	-	-	0.067	0.0516	-	-	-0.026	0.0497	-	-	-0.1978	0.0398
N				5,013				15,677				16,511

Standard errors are given in columns entitled s.e.
Source: Authors' calculations based on the GSOEP (1984-2012).

Table 7: Permanent and Transitory Variances over Age by Work Status.

Sample	Total				Employees				Self-Employed			
Age	$\hat{\sigma}^2_\psi$	s.e.	$\hat{\sigma}^2_\varepsilon$	s.e.	$\hat{\sigma}^2_\psi$	s.e.	$\hat{\sigma}^2_\varepsilon$	s.e.	$\hat{\sigma}^2_\psi$	s.e.	$\hat{\sigma}^2_\varepsilon$	s.e.
26	-	-	0.0279	0.0069	-	-	0.0220	0.0049	-	-	-0.0511	0.0547
27	0.0806	0.0074	0.0221	0.0041	0.0797	0.0084	0.0198	0.0030	0.2001	0.0776	0.0580	0.0443
28	0.0683	0.0073	0.0357	0.0073	0.0723	0.0066	0.0202	0.0034	0.0347	0.0600	0.1872	0.0813
29	0.0655	0.0060	0.0249	0.0041	0.0668	0.0057	0.0217	0.0031	0.0847	0.0645	-0.0222	0.0381
30	0.0611	0.0059	0.0283	0.0057	0.0595	0.0053	0.0228	0.0044	0.1669	0.0578	0.0628	0.0566
31	0.0494	0.0051	0.0289	0.0044	0.0498	0.0047	0.0218	0.0031	0.0605	0.0367	0.0889	0.0469
32	0.0564	0.0049	0.0283	0.0040	0.0533	0.0047	0.0219	0.0029	0.0825	0.0443	0.0654	0.0373
33	0.0408	0.0046	0.0269	0.0033	0.0409	0.0044	0.0210	0.0024	0.0522	0.0455	0.0716	0.0204
34	0.0317	0.0039	0.0302	0.0041	0.0336	0.0036	0.0229	0.0024	0.0379	0.0317	0.0499	0.0157
35	0.0375	0.0048	0.0332	0.0046	0.0374	0.0042	0.0253	0.0025	0.0693	0.0325	0.0576	0.0267
36	0.0380	0.0048	0.0275	0.0035	0.0329	0.0044	0.0215	0.0027	0.1237	0.0330	0.0469	0.0229
37	0.0277	0.0036	0.0303	0.0037	0.0273	0.0030	0.0221	0.0023	0.0784	0.0308	0.0681	0.0249
38	0.0297	0.0039	0.0337	0.0044	0.0262	0.0031	0.0266	0.0036	0.0778	0.0285	0.0545	0.0166
39	0.0225	0.0034	0.0299	0.0035	0.0231	0.0030	0.0207	0.0023	0.0623	0.0210	0.0474	0.0136
40	0.0260	0.0038	0.0265	0.0031	0.0246	0.0034	0.0208	0.0021	0.0774	0.0220	0.0357	0.0147
41	0.0216	0.0033	0.0258	0.0028	0.0218	0.0031	0.0202	0.0020	0.0557	0.0151	0.0309	0.0086
42	0.0286	0.0037	0.0230	0.0028	0.0236	0.0031	0.0177	0.0021	0.1087	0.0250	0.0340	0.0121
43	0.0240	0.0034	0.0259	0.0029	0.0219	0.0029	0.0199	0.0021	0.0719	0.0186	0.0321	0.0111
44	0.0243	0.0033	0.0267	0.0032	0.0241	0.0027	0.0199	0.0024	0.0549	0.0157	0.0352	0.0104
45	0.0207	0.0031	0.0307	0.0043	0.0181	0.0024	0.0228	0.0035	0.0930	0.0187	0.0378	0.0164
46	0.0218	0.0033	0.0338	0.0044	0.0213	0.0026	0.0243	0.0034	0.0722	0.0271	0.0825	0.0275
47	0.0218	0.0043	0.0329	0.0047	0.0199	0.0032	0.0219	0.0025	0.0622	0.0398	0.0784	0.0338
48	0.0242	0.0037	0.0255	0.0032	0.0227	0.0031	0.0186	0.0020	0.0770	0.0267	0.0262	0.0154
49	0.0253	0.0036	0.0241	0.0030	0.0215	0.0028	0.0207	0.0023	0.1084	0.0264	0.0252	0.0117
50	0.0261	0.0041	0.0255	0.0036	0.0257	0.0038	0.0204	0.0024	0.0678	0.0208	0.0352	0.0211
51	0.0281	0.0036	0.0300	0.0039	0.0217	0.0029	0.0249	0.0031	0.1142	0.0244	0.0403	0.0184
52	0.0222	0.0037	0.0287	0.0037	0.0211	0.0029	0.0209	0.0026	0.0669	0.0291	0.0649	0.0208
53	0.0179	0.0040	0.0316	0.0057	0.0181	0.0034	0.0268	0.0054	0.0417	0.0297	0.0376	0.0148
54	0.0273	0.0060	0.0370	0.0054	0.0255	0.0059	0.0298	0.0047	0.0757	0.0287	0.0611	0.0209
55	0.0274	0.0042	0.0267	0.0036	0.0249	0.0035	0.0183	0.0023	0.0688	0.0319	0.0606	0.0238
56	0.0332	0.0054	0.0260	0.0038	0.0334	0.0048	0.0177	0.0030	0.0544	0.0368	0.0592	0.0176
57	0.0304	0.0047	0.0284	0.0041	0.0304	0.0036	0.0195	0.0026	0.0686	0.0375	0.0668	0.0236
58	0.0273	0.0050	0.0362	0.0065	0.0320	0.0042	0.0236	0.0038	0.0140	0.0314	0.0962	0.0408
59	0.0302	0.0054	0.0268	0.0050	0.0263	0.0040	0.0208	0.0033	0.0529	0.0396	0.0395	0.0296
60	0.0238	0.0068	0.0355	0.0071	0.0253	0.0045	0.0190	0.0027	0.0436	0.0430	0.0737	0.0291
61	0.0231	0.0068	0.0352	0.0060	0.0298	0.0061	0.0220	0.0042	0.0336	0.0238	0.0574	0.0183
62	0.0234	0.0079	0.0406	0.0094	0.0304	0.0066	0.0226	0.0051	0.0570	0.0272	0.0603	0.0327
63	0.0267	0.0098	0.0358	0.0096	0.0206	0.0052	0.0144	0.0037	0.1252	0.0365	0.0393	0.0291
64	0.0552	0.0185	0.0483	0.0123	0.0165	0.0094	0.0271	0.0088	0.1908	0.0613	0.0534	0.0244
65	-	-	0.1053	0.0225	-	-	0.0394	0.0148	-	-	0.1930	0.0743
Mean	0.0334	0.0052	0.0320	0.0053	0.0317	0.0042	0.0221	0.0035	0.0786	0.0342	0.0560	0.0275
AR(1)	1	-	0.3629	0.1391	1	-	0.0968	0.0987	1	-	-0.4351	0.0753
MA(1)	-	-	-0.1495	0.0963	-	-	0.0821	0.074	-	-	0.3261	0.0891
N				23,241				21,425				3,258

Standard errors are given in columns entitled s.e.
Source: Authors' calculations based on the GSOEP (1984-2012).

Table 8: Permanent and Transitory Variances over Age by Occupation.

Sample	Blue Collar				White Collar				Civil Servant			
Age	$\hat{\sigma}^2_\psi$	s.e.	$\hat{\sigma}^2_\varepsilon$	s.e.	$\hat{\sigma}^2_\psi$	s.e.	$\hat{\sigma}^2_\varepsilon$	s.e.	$\hat{\sigma}^2_\psi$	s.e.	$\hat{\sigma}^2_\varepsilon$	s.e.
26	-	-	0.0159	0.0048	-	-	0.0188	0.0075	-	-	-0.0053	0.0252
27	0.0526	0.0068	0.0205	0.0037	0.1007	0.0124	0.0170	0.0048	0.0860	0.0443	0.0245	0.0184
28	0.0533	0.0097	0.0191	0.0048	0.1020	0.0106	0.0212	0.0056	0.0261	0.0136	0.0193	0.0112
29	0.0528	0.0061	0.0208	0.0039	0.0769	0.0100	0.0204	0.0044	0.0506	0.0171	0.0201	0.0112
30	0.0409	0.0060	0.0214	0.0036	0.0762	0.0092	0.0233	0.0082	0.0488	0.0134	0.0219	0.0181
31	0.0325	0.0058	0.0255	0.0053	0.0595	0.0080	0.0213	0.0040	0.0673	0.0190	0.0023	0.0129
32	0.0372	0.0049	0.0161	0.0027	0.0601	0.0071	0.0222	0.0038	0.0758	0.0326	0.0218	0.0254
33	0.0336	0.0050	0.0211	0.0034	0.0528	0.0074	0.0152	0.0031	0.0350	0.0165	0.0168	0.0118
34	0.0250	0.0044	0.0237	0.0032	0.0441	0.0058	0.0216	0.0032	0.0236	0.0125	0.0250	0.0123
35	0.0317	0.0049	0.0241	0.0035	0.0418	0.0071	0.0232	0.0034	0.0251	0.0098	0.0235	0.0092
36	0.0318	0.0063	0.0186	0.0031	0.0382	0.0072	0.0197	0.0039	0.0131	0.0099	0.0266	0.0135
37	0.0244	0.0039	0.0185	0.0024	0.0276	0.0043	0.0244	0.0036	0.0370	0.0147	0.0213	0.0106
38	0.0308	0.0046	0.0201	0.0028	0.0280	0.0045	0.0298	0.0064	-0.0036	0.0114	0.0340	0.0136
39	0.0201	0.0033	0.0217	0.0031	0.0238	0.0047	0.0189	0.0033	0.0277	0.0140	0.0140	0.0062
40	0.0286	0.0068	0.0212	0.0032	0.0233	0.0038	0.0217	0.0028	0.0245	0.0084	0.0088	0.0052
41	0.0272	0.0043	0.0202	0.0025	0.0182	0.0047	0.0205	0.0027	0.0194	0.0092	0.0113	0.0065
42	0.0220	0.0036	0.0149	0.0022	0.0250	0.0051	0.0162	0.0027	0.0201	0.0078	0.0165	0.0066
43	0.0277	0.0056	0.0236	0.0038	0.0228	0.0040	0.0176	0.0026	0.0027	0.0041	0.0129	0.0049
44	0.0270	0.0044	0.0160	0.0036	0.0258	0.0039	0.0209	0.0033	0.0107	0.0073	0.0168	0.0096
45	0.0311	0.0060	0.0182	0.0029	0.0159	0.0033	0.0221	0.0033	0.0068	0.0081	0.0202	0.0116
46	0.0214	0.0042	0.0204	0.0031	0.0227	0.0034	0.0278	0.0059	0.0109	0.0063	0.0151	0.0068
47	0.0271	0.0040	0.0188	0.0028	0.0178	0.0055	0.0244	0.0038	0.0052	0.0054	0.0166	0.0064
48	0.0305	0.0053	0.0169	0.0023	0.0203	0.0047	0.0196	0.0029	0.0098	0.0056	0.0151	0.0066
49	0.0274	0.0045	0.0170	0.0031	0.0191	0.0040	0.0246	0.0036	0.0085	0.0063	0.0139	0.0058
50	0.0317	0.0071	0.0174	0.0030	0.0276	0.0055	0.0192	0.0027	0.0002	0.0103	0.0325	0.0158
51	0.0262	0.0041	0.0207	0.0033	0.0213	0.0043	0.0267	0.0048	0.0125	0.0083	0.0222	0.0125
52	0.0250	0.0042	0.0194	0.0028	0.0231	0.0047	0.0215	0.0041	0.0047	0.0070	0.0208	0.0108
53	0.0195	0.0043	0.0214	0.0041	0.0198	0.0056	0.0337	0.0102	0.0011	0.0053	0.0172	0.0066
54	0.0211	0.0054	0.0338	0.0087	0.0287	0.0109	0.0304	0.0067	0.0074	0.0059	0.0153	0.0071
55	0.0206	0.0055	0.0218	0.0041	0.0274	0.0055	0.0190	0.0030	0.0131	0.0040	0.0068	0.0038
56	0.0359	0.0092	0.0164	0.0033	0.0355	0.0068	0.0214	0.0051	0.0137	0.0057	0.0077	0.0047
57	0.0396	0.0059	0.0201	0.0041	0.0261	0.0052	0.0187	0.0035	0.0091	0.0086	0.0210	0.0097
58	0.0305	0.0077	0.0284	0.0070	0.0398	0.0066	0.0214	0.0058	0.0108	0.0045	0.0156	0.0060
59	0.0348	0.0071	0.0130	0.0035	0.0311	0.0065	0.0239	0.0053	0.0047	0.0046	0.0127	0.0051
60	0.0237	0.0082	0.0253	0.0052	0.0270	0.0066	0.0177	0.0038	0.0180	0.0078	0.0104	0.0054
61	0.0117	0.0072	0.0342	0.0119	0.0384	0.0101	0.0177	0.0052	0.0173	0.0100	0.0186	0.0082
62	0.0312	0.0127	0.0173	0.0063	0.0355	0.0107	0.0253	0.0083	0.0252	0.0080	0.0064	0.0036
63	0.0264	0.0111	0.0069	0.0051	0.0170	0.0069	0.0155	0.0054	0.0205	0.0121	0.0134	0.0091
64	0.0528	0.0259	0.0034	0.0039	0.0172	0.0132	0.0267	0.0121	-0.0022	0.0183	0.0317	0.0233
65	-	-	0.0012	0.0109	-	-	0.0628	0.0280	-	-	0.0238	0.0128
Mean	0.0307	0.0065	0.0194	0.0042	0.0357	0.0066	0.0229	0.0053	0.0207	0.0110	0.0172	0.0103
AR(1)	1	-	-4.17E-04	3.00E-04	1	-	-9.07E-04	0.0032	1	-	0.4707	0.3721
MA(1)	-	-	0.1583	0.0194	-	-	0.1507	0.0202	-	-	-0.1437	0.1843
N				9,580				12,772				1,975

Standard errors are given in columns entitled s.e.
Source: Authors' calculations based on the GSOEP (1984-2012).

Table 9: Permanent and Transitory Variances over Age by Marital Status.

Sample	Married with Children				Single			
Age	$\hat{\sigma}^2_\psi$	s.e.	$\hat{\sigma}^2_\varepsilon$	s.e.	$\hat{\sigma}^2_\psi$	s.e.	$\hat{\sigma}^2_\varepsilon$	s.e.
26	-	-	0.0317	0.0112	-	-	0.0412	0.0137
27	0.0524	0.0109	0.0539	0.0132	0.0329	0.0130	0.0186	0.0067
28	0.0414	0.0167	0.0518	0.0139	0.0350	0.0095	0.0178	0.0045
29	0.0423	0.0081	0.0276	0.0058	0.0422	0.0092	0.0217	0.0060
30	0.0389	0.0092	0.0377	0.0107	0.0503	0.0125	0.0163	0.0063
31	0.0336	0.0069	0.0335	0.0067	0.0389	0.0079	0.0172	0.0045
32	0.0447	0.0067	0.0283	0.0054	0.0283	0.0067	0.0218	0.0050
33	0.0311	0.0056	0.0301	0.0048	0.0187	0.0080	0.0137	0.0046
34	0.0230	0.0041	0.0254	0.0042	0.0298	0.0096	0.0228	0.0058
35	0.0388	0.0076	0.0324	0.0054	0.0181	0.0074	0.0173	0.0043
36	0.0349	0.0064	0.0327	0.0056	0.0538	0.0176	0.0142	0.0046
37	0.0178	0.0044	0.0331	0.0050	0.0200	0.0082	0.0172	0.0042
38	0.0246	0.0052	0.0328	0.0063	0.0158	0.0080	0.0246	0.0105
39	0.0174	0.0044	0.0309	0.0051	0.0158	0.0085	0.0346	0.0121
40	0.0192	0.0050	0.0312	0.0052	0.0174	0.0100	0.0241	0.0076
41	0.0137	0.0039	0.0291	0.0045	0.0090	0.0081	0.0145	0.0041
42	0.0206	0.0047	0.0250	0.0042	0.0081	0.0074	0.0140	0.0045
43	0.0162	0.0044	0.0311	0.0047	0.0272	0.0090	0.0187	0.0064
44	0.0147	0.0035	0.0262	0.0042	0.0511	0.0280	0.0274	0.0100
45	0.0144	0.0053	0.0364	0.0068	0.0221	0.0137	0.0324	0.0119
46	0.0148	0.0042	0.0340	0.0067	0.0132	0.0115	0.0334	0.0122
47	0.0153	0.0062	0.0308	0.0070	0.0195	0.0129	0.0347	0.0097
48	0.0165	0.0057	0.0335	0.0059	0.0190	0.0095	0.0121	0.0066
49	0.0228	0.0051	0.0247	0.0044	0.0127	0.0092	0.0154	0.0062
50	0.0256	0.0064	0.0247	0.0047	0.0033	0.0059	0.0211	0.0095
51	0.0241	0.0046	0.0280	0.0047	0.0122	0.0072	0.0169	0.0048
52	0.0212	0.0049	0.0269	0.0051	0.0087	0.0084	0.0223	0.0075
53	0.0198	0.0051	0.0243	0.0045	0.0079	0.0101	0.0176	0.0128
54	0.0173	0.0047	0.0302	0.0054	0.0760	0.0346	0.0218	0.0199
55	0.0260	0.0072	0.0324	0.0063	0.0121	0.0142	0.0529	0.0290
56	0.0207	0.0080	0.0345	0.0068	0.0376	0.0156	0.0013	0.0073
57	0.0296	0.0109	0.0397	0.0101	0.0414	0.0130	0.0024	0.0039
58	0.0212	0.0104	0.0510	0.0119	0.0418	0.0127	0.0058	0.0073
59	0.0304	0.0098	0.0235	0.0080	0.0347	0.0134	0.0057	0.0040
60	0.0390	0.0152	0.0474	0.0146	0.0247	0.0135	0.0085	0.0049
61	0.0270	0.0124	0.0306	0.0086	0.0241	0.0158	-0.0015	0.0068
62	-0.0014	0.0201	0.0662	0.0313	0.0061	0.0268	0.0502	0.0418
63	0.0158	0.0259	0.0566	0.0285	0.0545	0.0292	-0.0001	0.0056
64	0.0495	0.0244	0.0278	0.0098	0.1236	0.1222	0.0395	0.0317
65	-	-	0.0215	0.0132	-	-	0.1387	0.1430
Mean	0.0257	0.0083	0.0337	0.0083	0.0291	0.0155	0.0232	0.0128
AR(1)	1	-	0.4117	0.1822	1	-	-0.5237	0.0614
MA(1)	-	-	-0.1631	0.1249	-	-	0.5514	0.0484
N				12,663				3,012

Standard errors are given in columns entitled s.e.
Source: Authors' calculations based on the GSOEP (1984-2012).