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# Insurance, Redistribution, and the Inequality of Lifetime Income

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## Abstract

Individuals vary considerably in how much they earn during their lifetimes. We study how the tax-and-transfer system offsets inequalities in lifetime earnings, which would otherwise translate into differences in living standards. Based on a life-cycle model, we find that redistribution by taxes and transfers offsets 54% of the inequality in lifetime earnings that is due to heterogeneous skill endowments. Meanwhile, taxes and transfers insure 45% of lifetime earnings risk. Taxes would provide more insurance if based on lifetime instead of annual earnings. Requiring wealthy individuals to repay social assistance received when younger would strengthen the insurance and redistributive functions of social assistance.

**Key words:** Lifetime earnings; lifetime income; tax-and-transfer system; taxation; unemployment insurance; disability benefits; social assistance; inequality; redistribution; insurance; endowments; risk; dynamic life-cycle models.

**JEL classification:** D63; H23; I24; I38; J22; J31.

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# 1 Introduction

The inequality of lifetime earnings is a key barometer of disparities in living standards. Indeed, to the degree that individuals can save and borrow, the inequality of lifetime earnings captures fundamental economic disparities more accurately than the inequality of annual earnings. Motivated by this observation, a growing literature has started to document the inequality of lifetime earnings. Despite the mobility of individuals in the earnings distribution, the inequality of lifetime earnings is substantial: Bönke et al. (2015) find that the distribution of the lifetime earnings of German men has a Gini coefficient around 0.2, and Guvenen et al. (2017) find that the 75th percentile of the lifetime earnings of American workers is around three times higher than the 25th percentile. Based on decompositions of the inequality of lifetime earnings, several studies have shown that the inequality in lifetime earnings is due to a combination of differences in skill endowments that are allotted early in life and chance differences in the shocks that individuals experience during their lifetimes (e.g., Bowlus and Robin, 2004, Huggett et al., 2011).

In this paper, we study how well the tax-and-transfer system mitigates the inequalities in lifetime earnings that are due to endowments and we show how the tax-and-transfer system moderates the disparities in lifetime earnings that are due to shocks. We call the former effect the redistributive effect of the tax-and-transfer system and we call the latter effect the insurance effect of the tax-and-transfer system. While previous studies have shown that the inequality of lifetime after-tax-and-transfer earnings (i.e., lifetime income) is lower than the inequality of lifetime earnings, we separately study how the tax-and-transfer system redistributes lifetime earnings and how it insures lifetime earnings risk.

There are three reasons why it is important to separate the insurance and redistributive effects of the tax-and-transfer system on lifetime income. First, information about the redistributive effect of the tax-and-transfer system speaks to how well taxes and transfers mitigate increases in the inequality of lifetime earnings that are driven by economic shifts that increase the returns to skill endowments. Relevant shifts include technological change that favors high ability workers and changes in the pattern of international trade that drive up the wage premium for a college degree. Second, studying how well taxes and transfers insure lifetime earnings risk highlights additional benefits from taxation, social assistance (or ‘welfare’) programs, and social insurance programs, such as unemployment insurance and disability benefits, compared to benefit calculations that focus on the effects of these programs on annual income or other short-term income measures. Third, by documenting the insurance and redistributive effects of the tax-and-transfer system, we are able to identify directions for policy reforms to taxes and social assistance that may improve the lifetime insurance and redistributive effects of the tax-and-transfer system.

Our empirical analysis focuses on Germany. In line with most developed countries, the German tax-and-transfer system features progressive taxes, disability benefits that are available to people who are experiencing bad health, unemployment insurance that provides temporary

income replacement following a job loss, and social assistance that provides long-term support to low-income wealth-poor individuals. We study the link between lifetime earnings, taxes and transfers, and lifetime income by embedding a tax-and-transfer system based on the German system into a dynamic life-cycle model of labor supply and consumption behavior. The model generates individual-level trajectories for earnings and after-tax-and-transfer income over the life cycle. The model thus provides the information that is needed to calculate lifetime earnings and lifetime income on an individual-by-individual basis. The model includes two key drivers of disparities in lifetime earnings: differences in skill endowments, specifically education and productive ability, and differences in the employment, health, and wage shocks that individuals encounter during their lifetimes.

We estimate the parameters of the life-cycle model by using a Maximum Likelihood procedure that targets the patterns of labor supply and earnings that we observe in a sample of men taken from the German Socio-Economic Panel (SOEP). We demonstrate that the estimated model has good in-sample fit. We also perform a validation exercise that shows that inequality in lifetime earnings predicted by the estimated model matches the inequality in lifetime earnings observed in a comparable administrative dataset that was not used for estimation.

We find that the tax-and-transfer system is strongly progressive on a lifetime basis, despite taxes and transfers being based on annual earnings. Both insurance and redistribution contribute to the progressive effect of the tax-and-transfer system on lifetime income. In particular, we find that the tax-and-transfer system mitigates 54% of the inequality in lifetime earnings that is due to shocks that individuals experience during their lives. Meanwhile, our results on redistribution suggest that the tax-and-transfer system will absorb 45% of any additional inequality in lifetime earnings that is generated by skill-biased technological change or other economic shifts that increase the returns to skill endowments.

We disaggregate the overall insurance and redistributive effects of the tax-and-transfer system into components due to taxes, unemployment insurance, disability benefits, and social assistance. We find that taxes are much more effective at redistributing lifetime income than insuring lifetime earnings risk. We trace the smaller insurance effect of taxes to the fact that a progressive tax on annual earnings cannot mitigate inequalities in lifetime earnings that arise from differences in the number of years that individuals work during their lifetimes together with the empirical reality that most of the inequality in lifetime earnings among individuals with the same endowments is due to differences in working behavior. We find that social assistance is the most important transfer program for both insurance and redistribution. Interestingly, the wealth test for social assistance, which restricts benefits to individuals with limited assets, reduces the insurance effect of social assistance. This reflects that, among individuals with identical endowments of education and productive ability, the wealth test bites most often on individuals with intermediate lifetime earnings. We also find that unemployment insurance and disability benefits provide insurance, however, unemployment insurance redistributes lifetime earnings whereas disability benefits are not redistributive.

In further analysis, we explore how the tax-and-transfer system insures three specific sources

of lifetime earnings risk: job separation risk; job offer risk; and health risk. Our results show that the tax-and-transfer system insures around 60% of the additional inequality in lifetime earnings arising from an increase in risk, irrespective of the source of the risk. However, the source of the risk to lifetime earnings affects the relative importance of unemployment insurance, disability benefits, and social assistance in providing insurance. In particular, unemployment insurance offers better insurance against earnings risk due to job separation risk than against earnings risk due to job offer risk. Disability benefits, meanwhile, offer better insurance against earnings risk due to the risk of bad health than against earnings risk due to job separation or job offer risk, although the insurance that disability benefits provide against employment risk is important. Social assistance is particularly effective at providing insurance against the additional earnings risk that arises from a decrease in the job offer rate.

Our findings suggest two directions for policy reforms that may improve the lifetime insurance and redistributive effects of the tax-and-transfer system. First, the relatively small insurance effect of progressive annual taxes that we find highlights a drawback of annual taxation relative to multi-year or lifetime taxation. A progressive tax on lifetime earnings would directly target differences in lifetime earnings between individuals with the same skill endowments and, therefore, would be more effective at insuring lifetime earnings risk than an annual tax. Second, our finding that the wealth test for social assistance reduces the lifetime insurance effect of the tax-and-transfer system suggests that the insurance effect of social assistance may be improved without increasing costs by switching to a lifetime wealth test that requires individuals with high wealth later in life to repay any social assistance they previously received. Switching to a lifetime wealth test for social assistance may also improve the redistributive effect of social assistance because most of the social assistance expenditures recouped under the lifetime wealth test would come from individuals with high expected lifetime earnings.

Our interest in the inequality of lifetime income is based on studies that document substantial inequities in lifetime earnings using administrative datasets (Björklund, 1993, Kopczuk et al., 2010, Aaberge and Mogstad, 2015, Bönke et al., 2015, Guvenen et al., 2017), statistical models (Bonhomme and Robin, 2009), or behavioral economic models (Bowlus and Robin, 2004, Bowlus and Robin, 2012, Brewer et al., 2012). Our focus on the insurance and redistributive effects of the tax-and-transfer system is motivated by a related literature that shows that both risk and skill endowments contribute to the inequality of lifetime outcomes (e.g., Keane and Wolpin, 1997, Flinn, 2002, Bowlus and Robin, 2004, Storesletten et al., 2004, Huggett et al., 2011). The importance of risk in explaining disparities in lifetime earnings is consistent with studies that show that individuals are subject to persistent earnings, health, and employment shocks (e.g., Meghir and Pistaferri, 2011). The role of skill endowments in driving lifetime earnings aligns with studies showing that education and non-cognitive skills are important determinants of lifetime earnings (e.g., Bhuller et al., 2017, Nybom, 2017).

Several papers have looked at the reallocative effect of taxes and transfers on a lifetime basis (e.g., Falkingham and Harding, 1996, Nelissen, 1998, Björklund and Palme, 2002, Pettersson and Pettersson, 2007, Ter Rele et al., 2007, Bovenberg et al., 2008, Bartels, 2012, Levell et al.,

2017). This literature systematically finds that the reallocation of lifetime earnings through the tax-and-transfer system partially offsets disparities in lifetime earnings. Levell et al. (2017), for example, find that the inequality of lifetime income in the UK is about 25% lower than the inequality of lifetime earnings. Levell et al. (2017) further show that in-work benefits and out-of-work benefits are equally effective at reducing the inequality of lifetime income. Other papers have taken a longitudinal perspective by looking at the dynamics of earnings and income at the individual level. In this vein, Blundell et al. (2015) show that taxes and transfers moderate the impact of transitory and permanent earnings shocks and Brewer and Shaw (2018) show that the marginal tax rate that individuals face varies more within life cycle than across individuals. However, in contrast to our analysis, the previous literature has not separately considered how the tax-and-transfer system targets inequalities in lifetime earnings that are due to risk and how taxes and transfers mitigate the inequality in lifetime earnings that is attributable to skill endowments.

Our life-cycle model of labor supply and consumption is in the spirit of the models introduced by Eckstein and Wolpin (1989), Keane and Wolpin (1997), and Imai and Keane (2004). Since we require information about lifetime income, as well as lifetime earnings, we follow, e.g., Low et al. (2010), Hoynes and Luttmer (2011), Shaw (2014), Low and Pistaferri (2015), Haan and Prowse (2015), and Blundell et al. (2016) by embedding a tax-and-transfer system into a life-cycle model. This literature has considered individuals' willingness to pay for particular elements of the tax-and-transfer system and, in many cases, has differentiated willingness to pay by education or other endowments. In contrast, we focus on the implications of taxes and transfers for the inequality of lifetime income. In doing so, we make a connection to a literature that links inequality to broader economic and socio-economic outcomes (see, e.g., Kelly, 2000, Panizza, 2002, Cramer, 2003).

This paper proceeds as follows. In Section 2 we introduce our definitions of lifetime earnings and lifetime income. In Section 3 we describe the life-cycle model that we use to derive lifetime earnings and lifetime income. In Section 4 we discuss our parameter estimates and present the results of a model validation exercise. In Section 5 we explore the insurance and redistributive effects of the tax-and-transfer system and in Section 6 we show how the tax-and-transfer system insures job separation risk, job offer risk, and health risk. In Section 7 we conclude by discussing some implications of our results.

## 2 Earnings and income concepts

We start with our definitions of earnings and income. An individual's annual earnings is composed of annual labor earnings and annual interest income. Using  $i$  to index individuals and  $t$  to denote age (measured in years), we have:

$$\text{Earnings}_{i,t} = \text{LaborEarnings}_{i,t} + \text{InterestIncome}_{i,t}. \quad (1)$$

We define the individual’s annual income at age  $t$  to be equal to his annual earnings, defined above, minus annual taxes plus the annual value of any government transfers:

$$\text{Income}_{i,t} = \text{Earnings}_{i,t} - \text{Taxes}_{i,t} + \text{Transfers}_{i,t}. \quad (2)$$

In other words, we use the term income to refer to after-tax-and-transfer earnings. Summing the individual’s annual earnings over the life cycle yields the individual’s lifetime earnings. Likewise, the individual’s lifetime income is obtained by summing the individual’s annual income over the life cycle.

While the exact nature of tax and transfer programs varies from one country to another, there are some broad similarities in how countries organize these programs. First, taxes are generally based on annual income and are progressive on an annual basis. Second, transfer programs typically include provisions for people experiencing bad health or disabilities, unemployment insurance that provides temporary income replacement following a job loss, and social assistance (i.e., welfare) that provides support to low income, wealth-poor individuals, irrespective of their earnings history. Since these transfer programs support individuals when they experience low income, they are also progressive on an annual basis. In our analysis, we consider a tax-and-transfer system that includes progressive annual taxation along with unemployment insurance, disability benefits and social assistance. To align with our data, the tax-and-transfer system that we consider is based on the German system. Sections 2.1 and 2.2 provide further details.

## 2.1 Transfers

Transfers include unemployment insurance, disability benefits and social assistance.<sup>1</sup>

**Unemployment insurance:** An individual who enters unemployment from employment receives unemployment insurance for one year. Unemployment insurance is equal to sixty percent of the individual’s after-tax labor earnings in the year before he entered unemployment.

**Disability benefits:** An individual in bad health may choose to enter disability-based retirement, irrespective of his age. Once in disability-based retirement, an individual receives disability benefits each year for the rest of his life. Disability benefits increase with earnings prior to retirement, and include an experience credit of one year for each year that the individual entered disability-based retirement before age 63 years.<sup>2</sup>

**Social assistance:** Social assistance guarantees every individual a minimum annual income. In particular, if an individual’s combined annual income from labor earnings, interest income,

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<sup>1</sup>The model also includes pension benefits for individuals in old-age retirement (see Appendix I).

<sup>2</sup>Specifically, an individual who enters retirement in bad health at age  $R$  receives an annual disability benefit of:

$$\alpha \times \bar{W}_R \times \text{DBPenalty}_R \times (\text{Exper}_R + \text{Credit}_R),$$

unemployment insurance and disability benefits is below the annual minimum income guaranteed by social assistance then the individual receives a social assistance transfer to increase his annual income to the level of the annual minimum income guarantee. The annual minimum income guarantee ranges from 8,400 euros per year if the individual has no assets to zero if the individual is sufficiently wealthy. In more detail, the annual minimum income guaranteed by social assistance is equal to:

$$\max\{8,400 - \max\{A_{i,t} - 10,000 - 500 \times (t - 20), 0\}, 0\},$$

where  $A_{i,t}$  denotes the individual's assets at age  $t$ . Intuitively, the annual minimum income guarantee is adjusted downwards by one euro for each euro of assets in excess of an age-specific disregard. The age-specific disregard starts at 10,000 euros for an individual who is aged 20 years and increases by 500 euros with each year of age.

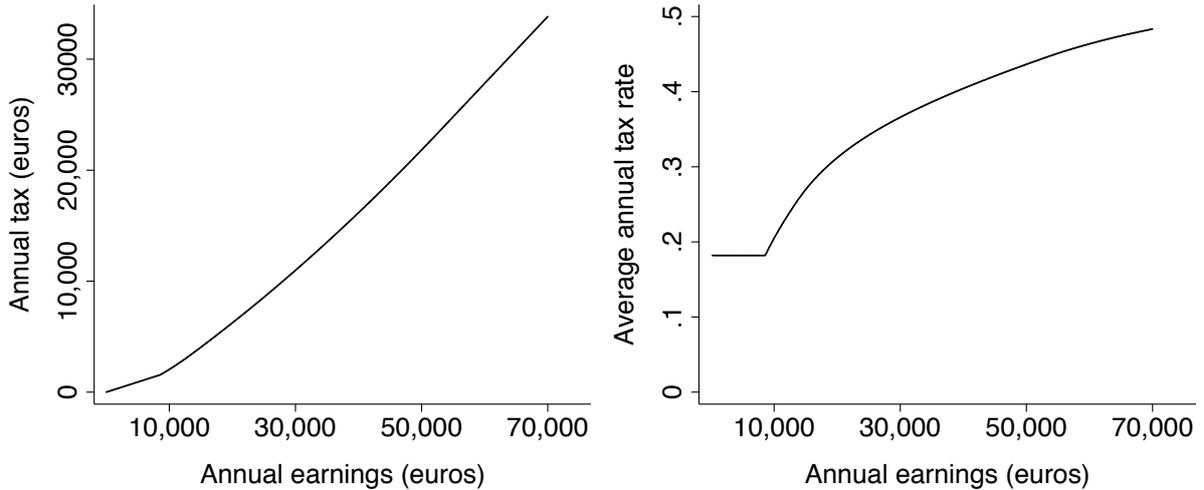
## 2.2 Taxes

Individuals face three annual taxes: a tax on annual labor earnings; a tax on annual interest income; and a social security tax on annual labor earnings. Figure 1 shows the tax on annual earnings and the associated average tax rate (assuming the individual has zero interest income). Taxation is strongly progressive on an annual basis: the average tax rate varies from 18.2% for individuals with labor earnings below 8,584 euros per year to 48% for individuals with labor earnings of 70,000 euros per year. The tax on annual interest income is a flat rate tax of 25% on interest income above an exemption and, therefore, is also progressive. Appendix II provides further details about taxes.

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where  $\alpha$  is a parameter that controls the generosity of disability benefits,  $\overline{W}_R$  is the individual's disability-benefit-eligible annual earnings averaged over all years of employment prior to retirement,  $DBPenalty_R$  is a penalty that reduces the individual's annual disability benefit by 3.6% for each year that he retired before the age of 63 years (up to a maximum reduction of 10.8%),  $Exper_R$  denotes the individual's experience at retirement (i.e., the number of years that the individual was employed during his life), and  $Credit_R$  is an experience credit of one year for each year that the individual is entered disability-based retirement before the age of 63 years. Only annual earnings below 72,374 euros are considered when calculating disability benefits.

Figure 1: Annual taxes



### 3 A model of lifetime income

Our analysis of the effect of taxes and transfers on the inequality of lifetime income requires individual-level information about earnings, taxes, and transfers in each year of the life cycle. Furthermore, to distinguish between the insurance and redistributive effects of the tax-and-transfer system, we need to link the individual-level measures of earnings and income to individuals' skill endowments.

We derive the required information about earnings, income and skill endowments from a dynamic life-cycle model. According to this model, in each year of the life cycle, each individual chooses a labor supply state ( $l$ ) and a level of consumption ( $c$ ) to maximize the discounted present value of his lifetime utility. The model includes three mutually exclusive labor supply states: employment, unemployment, and retirement.<sup>3</sup> Inequality in lifetime earnings may arise from differences between individuals' endowments or from different realizations of life-cycle risks. The model includes three sources of lifetime earnings risk: employment risk (from job separation risk and job offer risk), wage risk, and health risk. The model includes taxes and transfers, which allows us to explore how the tax-and-transfer system insures lifetime earnings risk and how it redistributes lifetime earnings. The model is described in Sections 3.1-3.8.

#### 3.1 Endowments

Each individual is endowed with a level of education and a productive ability. Individual  $i$ 's educational endowment,  $\text{Educ}_i \in \{7, \dots, 18\}$ , is equal to his years of schooling.<sup>4</sup> The individual's endowment of productive ability is given by  $\eta_i \in \{\eta_1, \eta_2, \eta_3\}$ . Combining the eleven possible

<sup>3</sup>Employment corresponds to 40 hours of work per week; this is the median hours of work per week for employees in the estimation sample. Unemployment includes individuals who are not willing to work at their market wage and individuals who are willing to work at their market wage but do not receive a job offer.

<sup>4</sup>If the individual has fewer than 12 years of schooling then he enters the labor force at age 20 years. Meanwhile, if the individual has 12 or more years of education then he enters the labor force at age  $\text{Educ}_i + 8$  years.

values of education with the three productive ability types gives a total of thirty-three distinct endowment groups. As we explain below, an individual’s endowment of education and productive ability may affect the health risk, employment risk, and wage risk that he faces during his lifetime. In this way, the model captures between-endowment inequality in lifetime earnings and lifetime income.

We allow the endowments of education and productive ability to be interrelated, which may occur if, e.g., individuals select into education based on their productive ability. We capture the relationship between education and productive ability by allowing an individual’s probability of being each of the three productive ability types to depend on his educational endowment. Formally, we use  $E \in \{1 \text{ “low education”}, 2 \text{ “high education”}\}$  to distinguish low education, defined as less than 12 years of education, and high education, defined as 12 or more years of education. We then specify that an individual with education in category  $E \in \{1, 2\}$  has a probability  $\rho_{j,E}$  of being endowed with productive ability  $\eta_j$ .<sup>5</sup>

### 3.2 Health risk

An individual’s health status is either good or bad. Individuals are in good health when they first enter the labor market. Health then evolves stochastically over the life cycle: each year, an individual in good health may be subject to a negative health shock, which transitions him into bad health, while an individual in bad health may be subject to a positive health shock, which transitions him into good health. The health transition probabilities depend on age, previous health status, and education as follows:

$$\text{Prob}(\text{GoodHealth}_{i,t} = 1) = G_t(\text{HighEduc}_i, \text{GoodHealth}_{i,t-1}), \quad (3)$$

where  $\text{GoodHealth}_{i,t}$  is an indicator of the individual being in good health at age  $t$ ,  $\text{HighEduc}_i$  is an indicator of the individual having been endowed with at least twelve years of education (high education) and  $G_t(\cdot)$  is an age-dependent nonparametric function. See Section 4.3 for further details.

### 3.3 Employment risk

Employment is feasible only if the individual receives a job offer in the current year. The likelihood of receiving a job offer in the current year depends on the individual’s employment status in the previous year. An individual who was employed in the previous year is subject to an involuntary job separation with probability  $\Phi_{i,t}^s$ . An individual who was unemployed in the previous year receives a job offer in the current year with probability  $\Phi_{i,t}^o$  while an individual who was employed in the previous year receives a job offer in the current year provided that they are not subject to an involuntary job separation. Retired individuals do not receive job

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<sup>5</sup>We impose  $\eta_1 > \eta_2 > \eta_3$ . This is for identification and is without loss of generality.

offers. The involuntary job separation and job offer probabilities are given by:

$$\begin{aligned} \Phi_{i,t}^k &= \Lambda(\phi_1^k + \phi_2^k \text{HighEduc}_i + \phi_3^k \text{GoodHealth}_{i,t} + \phi_4^k 1(t \geq 50) + \phi_5^k 1(t \geq 55) + \phi_6^k 1(t \geq 60)) \\ &\text{for } k \in \{s, o\}, \end{aligned} \quad (4)$$

where  $\Lambda(\cdot)$  denotes the logistic distribution function.

### 3.4 Retirement

An individual may retire only if he meets certain health- or age-based criteria. In particular, an individual may retire only if he is in bad health (disability-based retirement) or if he is age 63 years or older (old-age retirement). Retirement is compulsory at age 65 years, and once retired the individual remains retired until the end of the life cycle at age 78 years.

### 3.5 Wages and labor earnings

The log hourly wage is given by:

$$\begin{aligned} \log(\text{Wage}_{i,t}) &= \psi_1 \text{Educ}_i + (\psi_2 \text{Exper}_{i,t} + \psi_3 \text{Exper}_{i,t}^2) \times \text{LowEduc}_i + \\ &(\psi_4 \text{Exper}_{i,t} + \psi_5 \text{Exper}_{i,t}^2) \times \text{HighEduc}_i + \psi_6 \text{GoodHealth}_{i,t} + \eta_i + \kappa_{i,t} + \mu_{i,t} \end{aligned} \quad (5)$$

where  $\text{Exper}_{i,t}$  denotes experience, defined as the number of years that the individual was employed during his life prior to the current year,  $\text{LowEduc}_i$  is an indicator of the individual having been endowed with twelve or fewer years of education (low education),  $\eta_i$  is the individual's endowment of productive ability,  $\kappa_{i,t}$  is an autocorrelated wage shock, and  $\mu_{i,t} \sim \mathbb{N}(0, \sigma_\mu^2)$  is wage measurement error that occurs independently over time. If the individual was employed in the previous year then the autocorrelated wage shock evolves according to:

$$\kappa_{i,t} = \delta \kappa_{i,t-1} + \nu_{i,t}, \quad (6)$$

where  $\nu_{i,t} \sim \mathbb{N}(0, \sigma_\nu^2)$  and is independent over time. Meanwhile, if the individual was in education or unemployed in the previous year then  $\kappa_{i,t}$  is a draw from the steady state distribution of the autocorrelated wage shock.<sup>6</sup> Since employment entails 40 hours of work per week (see footnote 3), the annual labor earnings of employed individual  $i$  at age  $t$  are equal to  $\text{Wage}_{i,t} \times 40 \times 52$ .

### 3.6 Inter-temporal budget constraint

Assets,  $A_{i,t}$  are accumulated according to:

$$A_{i,t} = (1 + r) A_{i,t-1} + \text{LaborEarnings}_{i,t} - \text{Taxes}_{i,t} + \text{Transfers}_{i,t} - c_{i,t}, \quad (7)$$

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<sup>6</sup>In the steady state  $\kappa_{i,t} \sim \mathbb{N}(0, \sigma_\nu^2 / (1 - \delta^2))$ .

where  $c_{i,t}$  denotes the annual consumption of individual  $i$  at age  $t$  and  $r$  denotes the real interest rate (assumed to be equal to 0.02). The term  $rA_{i,t-1}$  in (7) thus denotes individual  $i$ 's annual interest income at age  $t$ .

### 3.7 Consumption and preferences

Individuals derive utility from consumption and leisure. The individual's per-period utility function is given by:

$$U(c_{i,t}, l_{i,t}) = \begin{cases} \alpha_1 \frac{c_{i,t}^{1-\gamma}}{1-\gamma} + \epsilon_{i,t}^1 & \text{if } l_{i,t} = \text{retired,} \\ \alpha_1 \frac{(c_{i,t}(\alpha_{2,1}\text{BadHealth}_{i,t} + \alpha_{2,2}\text{GoodHealth}_{i,t}))^{1-\gamma}}{1-\gamma} + \epsilon_{i,t}^2 & \text{if } l_{i,t} = \text{employed,} \\ \alpha_1 \frac{(c_{i,t}(\alpha_{3,1}\text{BadHealth}_{i,t} + \alpha_{3,2}\text{GoodHealth}_{i,t}))^{1-\gamma}}{1-\gamma} + \epsilon_{i,t}^3 & \text{if } l_{i,t} = \text{unemployed.} \end{cases} \quad (8)$$

For individuals in bad health,  $\alpha_{2,1}$  denotes the share of consumption enjoyed if employed and  $\alpha_{3,1}$  denotes the share for consumption enjoyed if unemployed. The corresponding preference parameters for individuals in good health are  $\alpha_{2,2}$  and  $\alpha_{3,2}$ .  $\gamma \equiv 0.5$  is the coefficient of relative risk aversion. The preference shocks  $\epsilon_{i,t}^1$ ,  $\epsilon_{i,t}^2$  and  $\epsilon_{i,t}^3$  are assumed to be type-1 extreme value distributed and independent over labor supply states and over time.  $\alpha_1$  is the weight given to the systematic utility from consumption and leisure relative to the preference shocks.

### 3.8 Optimal behavior

The individual's optimal consumption and labor supply choice at age  $t$  is given by:

$$\{c_{i,t}^*, l_{i,t}^*\} = \underset{\{c,l\} \in \mathbb{D}(\mathbf{s}_t)}{\text{argmax}} \{U(c, l, \epsilon_{i,t}) + \beta E_t[V_{t+1}(\mathbf{s}_{i,t+1}) | \mathbf{s}_{i,t}, c, l]\}. \quad (9)$$

In the above,  $\beta \equiv 0.99$  is the discount factor,  $\mathbb{D}(\mathbf{s}_t)$  is the set of choices that is available to the individual at age  $t$  (the choice set is determined by involuntary job separations, job offers, wealth and the age- and health-based restrictions on eligibility for retirement),  $V_{t+1}(\mathbf{s}_{i,t+1})$ , is the value function, i.e., the maximal expected discounted present value of lifetime utility at age  $t + 1$ , and  $\mathbf{s}_{i,t}$  denotes the state variables. The state variables are as follows:

$$\mathbf{s}_{i,t} \equiv \{\text{Educ}_i, \eta_i, t, \text{Health}_{i,t}, \text{Exper}_{i,t}, A_{i,t}, l_{i,t-1}, \text{Wage}_{i,t-1}, \nu_{i,t}, \text{JS}_{i,t}, \text{JO}_{i,t}, \epsilon_{i,t}\}, \quad (10)$$

where  $\text{JS}_{i,t}$  and  $\text{JO}_{i,t}$  are indicators of the individual receiving, respectively, an involuntary job separation and a job offer at age  $t$  and  $\epsilon_{i,t}$  is a vector that contains the individual's age- $t$

preference shocks.<sup>7</sup>

## 4 Parameter estimates and model validation

We estimate the parameters of the life-cycle model using an unbalanced annual panel sample of men from the German Socio-Economic Panel (SOEP).<sup>8</sup> Our estimation sample contains 3,281 distinct individuals and a total of 20,843 individual-year observations from the years 2004–2016. Appendix III describes the sample in more detail.

We estimate the model in two stages. First, we estimate the health transition probabilities given by (3) and the parameters that determine the involuntary job separation probabilities  $(\phi_1^s, \dots, \phi_6^s)$ . Specifically, we compute the empirical probability of good health for each combination of age, previous health status, and educational category (high or low education). We then smooth the age profiles of the empirical health probabilities using a Nadaraya-Watson kernel regression (Nadaraya, 1964, Watson, 1964) with an epanechnikov kernel and the rule-of-thumb bandwidth (Fan and Gijbels, 1996). The involuntary job separations are defined as transitions into unemployment that are due to the end of a fixed-term contract, a dismissal or a firm closure, or that occur when the individual has bad health. In the second stage of the estimation, we use a Maximum Likelihood procedure that targets the patterns of labor supply and wages that we observe in the sample to estimate the parameters that appear in the utility function, wage equation, and job offer probabilities. Appendix IV explains how we approximate the value function, presents the likelihood function, and describes how we maximize the likelihood function.

Sections 4.1–4.3 discuss the parameter estimates. Section 4.4 validates the estimated life-cycle model by showing that the model’s predictions about the inequality in annual and lifetime earnings are similar to the levels of inequality observed in a comparable administrative dataset that was not used for estimation. Appendix IV.4 shows that the estimated model has good in-sample fit.

### 4.1 Preferences and wages

Panel I of Table 1 reports our estimates of the parameters of the utility function. We estimate the disutility of employment relative to retirement to be 44.1% of consumption for individuals in good health and 35.4% for individuals in bad health. The estimated cost of unemployment amounts to 26.3% of consumption for individuals in good health and 12.9% for individuals in bad health. Panel II of Table 1 reports our estimates of the parameters of the wage equation. We find

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<sup>7</sup>We operationalize the model by assuming that the individual chooses a level of saving, and thus a level of consumption, from a finite set of alternatives. An employed individual chooses annual savings (in euros) from the set  $\{-5000, -2500, -1000, -500, 0, 500, 1000, 2500, 5000, 7500, 10000, 12500, 15000\}$ . An unemployed individual chooses annual savings (in euros) from the set  $\{-15000, -12500, -10000, -7500, -5000, -2500, -1000, -500, 0, 500, 1000, 2500, 5000\}$ . A retired individual dis-saves the annuity value of his wealth.

<sup>8</sup>Wagner et al. (2007) and Socio-Economic Panel (2013) describe the SOEP.

Table 1: Parameters of the utility function, wage equation and type probabilities

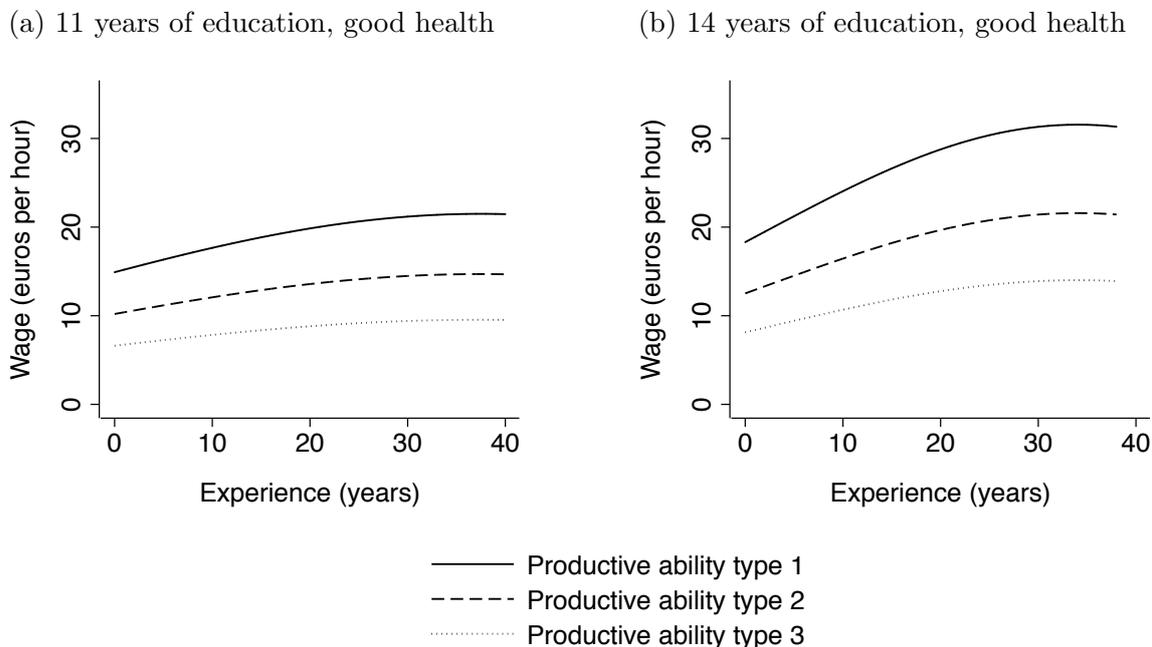
	Estimate	Standard error
Panel I: Utility function		
$\alpha_1$ (Weight on utility from consumption and leisure)	1.794	0.0778
$\alpha_{2,1} - 1$ (Disutility of employment, bad health)	-0.441	0.0202
$\alpha_{2,2} - 1$ (Disutility of employment, good health)	-0.354	0.0210
$\alpha_{3,1} - 1$ (Disutility of unemployment, bad health)	-0.129	0.0255
$\alpha_{3,2} - 1$ (Disutility of unemployment, good health)	-0.263	0.0267
Panel II: Wage equation		
$\eta_1$ (Intercept for productive ability type 1)	1.936	0.0402
$\eta_2$ (Intercept for productive ability type 2)	1.556	0.0402
$\eta_3$ (Intercept for productive ability type 3)	1.124	0.0455
$\psi_1$ (Educ/10)	0.683	0.0287
$\psi_2$ (Exper/10, low education)	0.195	0.0145
$\psi_3$ (Exper/10, high education)	0.320	0.0146
$\psi_4$ (Exper <sup>2</sup> /100, low education)	-0.026	0.0031
$\psi_5$ (Exper <sup>2</sup> /100, high education)	-0.047	0.0034
$\psi_6$ (Good health)	0.015	0.0055
$\delta$ (Autocorrelation of wage shocks)	0.937	0.0034
$\sigma_\nu$ (St.d. of wage shocks)	0.071	0.0014
$\sigma_\mu$ (St.d. of wage measurement error)	0.107	0.0008
Panel III: Productive ability type probabilities		
$\rho_{1,1}$ (Probability of productive ability type 1, low education)	0.437	0.0264
$\rho_{2,1}$ (Probability of productive ability type 2, low education)	0.525	0.0256
$\rho_{3,1}$ (Probability of productive ability type 3, low education)	0.038	0.0087
$\rho_{1,2}$ (Probability of productive ability type 1, high education)	0.370	0.0244
$\rho_{2,2}$ (Probability of productive ability type 2, high education)	0.499	0.0241
$\rho_{3,2}$ (Probability of productive ability type 3, high education)	0.131	0.0140

*Notes:* ‘Educ’ is years of education and ‘Exper’ is years of experience. Standard errors were derived from the Hessian of the log likelihood function at its maximum and using the delta method where required.

that wage shocks have a standard deviation of 0.071 and are highly persistent with 93.4% of a wage shock carrying through to the next year. The standard deviation of the wage measurement error is equal to 0.107. To aid in interpreting the remaining wage parameters, Figure 2 illustrates estimated wage profiles (excluding wage shocks) for six of the thirty-three endowment groups that we model. We find that wages vary strongly with both parts of individuals’ endowments (education and productive ability). We also find positive returns to experience (with a minor exception for individuals with close to the maximal level of experience). However, for the purpose of interpreting our later results, it is important to note that the variation in wages with experience within an endowment group is small and is much lower than the variation in wages between different endowment groups. The effect of health status on wages is negligible in magnitude (being in good health instead of bad health increases the wage by 1.5%). The small effect of health on wages that we find is similar to the estimates of French (2005).

Panel III of Table 1 shows that, for low educated individuals, we estimate that 43.7% are endowed with high productive ability (type 1), 52.5% are endowed with medium productive ability (type 2), and the remaining 3.8% are endowed with low productive ability (type 3). The corresponding percentages for high educated individuals are 37.0%, 49.9%, and 13.1%.

Figure 2: Estimated wage profiles (excluding wage shocks)



*Notes:* Wage profiles were calculated using the parameter estimates shown in Panel II of Table 1 and exclude wage shocks and wage measurement error.

## 4.2 Employment risk

Table 2 shows the estimated job offer and involuntary job separation probabilities. Individuals in bad health face higher involuntary job separation and lower job offer probabilities than individuals in good health. Conditional on health status, offer probabilities are lower after age 50, while separation probabilities decrease at age 50 and, then, increase after age 60. Conditional on health status and age, the job offer and involuntary job separation probabilities decrease with education, which implies that high educated individuals are both relatively unlikely to be forced out of employment and face a relatively long expected wait before receiving a job offer.

Table 2: Job offer and involuntary job separation probabilities

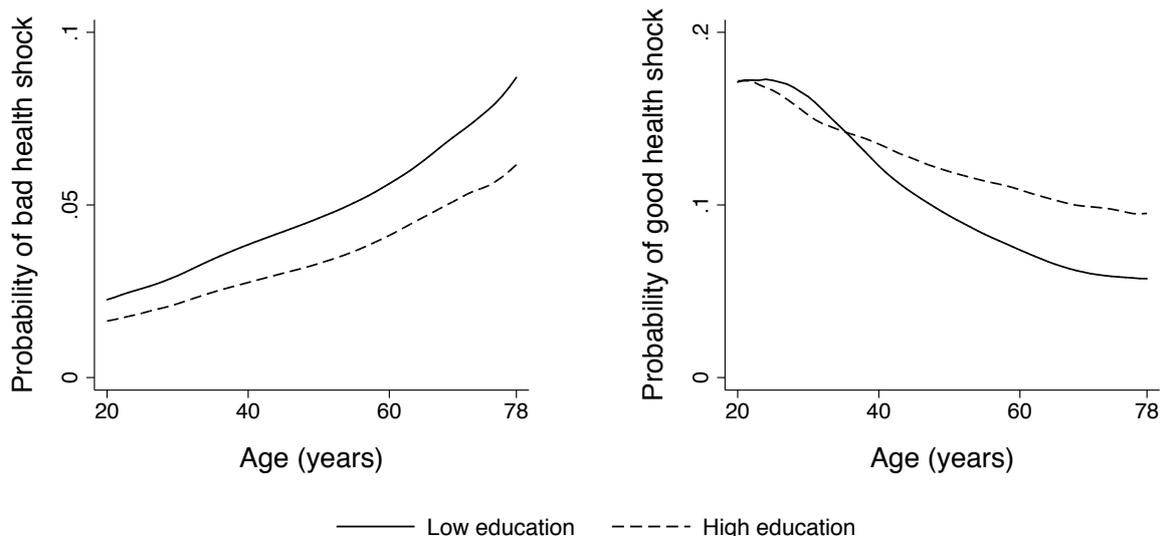
		Age<50	50≤Age<55	55≤Age<60	Age≥60
Panel I: Job offer probabilities					
Low education	Bad health	0.188 (0.0152)	0.113 (0.0133)	0.140 (0.0148)	0.109 (0.0161)
	Good health	0.385 (0.0139)	0.256 (0.0208)	0.306 (0.0209)	0.249 (0.0276)
High education	Bad health	0.159 (0.0136)	0.094 (0.0116)	0.117 (0.0131)	0.091 (0.0139)
	Good health	0.338 (0.0120)	0.219 (0.0188)	0.264 (0.0193)	0.213 (0.0246)
Panel II: Involuntary job separation probabilities					
Low education	Bad health	0.074 (0.0070)	0.060 (0.0079)	0.048 (0.0089)	0.076 (0.0175)
	Good health	0.019 (0.0016)	0.015 (0.0021)	0.012 (0.0025)	0.019 (0.0053)
High education	Bad health	0.041 (0.0046)	0.033 (0.0049)	0.026 (0.0054)	0.042 (0.0108)
	Good health	0.010 (0.0009)	0.008 (0.0012)	0.006 (0.0014)	0.010 (0.0030)

*Notes:* Reported probabilities were obtained by evaluating (4) using the estimated parameter values. Standard errors are shown in parentheses.

### 4.3 Health risk

Figure 3 shows the estimated profiles of health risk over the life cycle. Education is an important determinant of health. In particular, being highly educated decreases the likelihood of a bad health shock and increases the likelihood of a good health shock. Reflecting a general deterioration in health status over the life cycle, the probability of a bad health shock increases with age and the probability of a good health shock decreases with age for high and low educated individuals.

Figure 3: Health risk



*Notes:* Illustrated probabilities were obtained using the nonparametric estimation method described in Section 4.

## 4.4 Validation

We validate the estimated model by comparing the inequality on labor earnings that is predicted by the estimated model with the labor earnings inequality observed in a comparable sample that was not used for estimation. In particular, we use the estimated model to simulate a sample of life-cycle labor earnings profiles. We then compare the inequality of annual and lifetime labor earnings in the simulated sample to Bönke et al. (2015)'s calculations of the inequality of annual and lifetime labor earnings based on a sample of lifetime labor earnings histories taken from administrative social security records for Germany. The sample selection criteria used by Bönke et al. (2015) closely match the rules used for constructing our estimation sample (see Appendix III): both samples exclude civil servants, self-employed individuals, East Germans, and women. Our simulated sample and Bönke et al. (2015)'s sample exclude individuals aged 60 years or above.<sup>9</sup>

Table 3 reports the results of our validation exercise. The first row of this table shows that the inequality of annual labor earnings implied by the estimated model closely matches that observed in the sample of administrative social security records (the Gini coefficients are equal to 0.347 and 0.336, respectively). Of particular relevance for our later analysis, the second row of Table 3 shows that the inequality of lifetime labor earnings predicted by the estimated model also closely matches that observed in the sample of administrative social security records (the Gini coefficients are equal to 0.218 and 0.212, respectively). It follows that the estimated model replicates Bönke et al. (2015)'s finding that the inequality of lifetime labor earnings is around two-thirds of the inequality of annual labor earnings.

<sup>9</sup>Corneo (2015) reports further results from analysis of Bönke et al. (2015)'s sample. For further comparisons of the inequality of annual and lifetime earnings using administrative datasets of lifetime earnings see Kopczuk et al. (2010) and Guvenen et al. (2017) for the US, Björklund (1993) for Sweden, and Aaberge and Mogstad (2015) for Norway.

Table 3: Gini coefficients for annual and lifetime labor earnings

	Sample simulated using estimated model	Sample of administrative social security records	Estimation sample (from SOEP)
Annual labor earnings	0.347	0.336	0.316
Lifetime labor earnings	0.218	0.212	–

*Notes:* The simulated sample was constructed by using the estimated life-cycle model to simulate life-cycle trajectories of labor supply, health, wages, earnings, income and wealth for 10,000 individuals. Each individual in the simulated sample was endowed with a level of education and a productive ability. The empirical distribution of education in the simulated sample was chosen to match that observed in the estimation sample. The productive ability for each individual in the simulated sample was obtained by drawing from the estimated distribution of productivity (see Panel III of Table 1). The sample of administrative social security records was taken from the VSKT sample and is described in Bönke et al. (2015). The estimation sample from the SOEP is described in Appendix III. Gini coefficients for the sample of administrative social security records are taken from Bönke et al. (2015, Figure 1) and pertain to the 1949 birth cohort. The Gini coefficient for annual labor earnings for the estimation sample was calculated using re-weighting to replicate the (uniform) distribution of age in the other two samples. Observations of individuals aged 60 years or older are excluded from all calculations.

We also note that the inequality of annual labor earnings in the estimation sample is similar to the inequality of annual labor earnings in the simulated sample, which provides further support for the in-sample fit of the estimated model (see Appendix IV.4). The inequality of annual labor earnings in the estimation sample is also similar to the inequality of annual labor earnings in the sample of administrative social security records; this finding provides empirical support for the argument that the estimation sample and the sample of administrative social security records are comparable.

## 5 Taxes, transfers & the inequality of lifetime income

We now turn to our first contribution, which is to use the estimated model to understand how taxes and transfers insure lifetime earnings risk and how they redistribute lifetime earnings. Before proceeding, we must consider the measurement of inequality. Our question requires us to work with an inequality measure that is additively decomposable into within- and between-endowment components. The rules out using the Gini coefficient (see Cowell and Flachaire, 2015). Instead, our primary analysis focuses on the Theil index, which is a special case of the generalized entropy index. The Theil index for a sample of earnings (incomes)  $\{y_i\}_{i=1}^N$  is given by:

$$\frac{1}{N} \sum_{i=1}^N \frac{y_i}{\bar{y}} \ln \left( \frac{y_i}{\bar{y}} \right), \quad (11)$$

where  $\bar{y}$  denotes the sample mean of earnings (income).

We check the robustness of our results by reevaluating inequality using two alternative generalized entropy measures, namely the squared coefficient of variation and the mean logarithmic

deviation. Compared to the Theil index, the squared coefficient of variation gives less weight to inequality at the bottom of the distribution. Conversely, the mean logarithmic deviation gives more weight than the Theil index to inequality at the bottom of the distribution. Despite these differences, we show that our qualitative results hold irrespective of whether we measure inequality using the Theil index, the squared coefficient of variation, or the mean logarithmic deviation.<sup>10</sup>

## 5.1 Insurance and redistributive effects of taxes and transfers

Using the Theil index, we have the following decomposition of the inequality of lifetime income:

$$\text{Inequality of lifetime income} = \text{Within-endowment inequality of lifetime income} + \text{Between-endowment inequality of lifetime income}. \quad (12)$$

The between-endowment inequality of lifetime income is a summary measure of the differences in average lifetime income between individuals with different endowments of education and productive ability. We define the redistributive effect of the tax-and-transfer system as the difference between the between-endowment inequality of lifetime earnings and the between-endowment inequality of lifetime income. The within-endowment inequality of lifetime income reflects differences in lifetime income among individuals with the same endowment of education and productive ability. The within-endowment inequality of lifetime income is, therefore, a summary measure of the lifetime income consequences of risks that individuals cannot insure themselves against. We assess the insurance function of taxes and transfers by looking at how the tax-and-transfer system affects the within-endowment inequality of lifetime income.<sup>11</sup>

We quantify each component of (12) using a sample of life-cycle income trajectories simulated from the estimated model. We repeat this exercise using earnings instead of income (the notes to Table 3 describe how we use the estimated model to simulate earnings and income trajectories). These calculations reveal the effect of taxes and transfers on the inequality of lifetime income or, equivalently, the share of lifetime earnings inequality that is offset by taxes and transfers. Throughout this exercise, we continue to focus on earnings and incomes of individuals younger than 60 years. In so doing, we abstract from the effects of old-age retirement

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<sup>10</sup>The squared coefficient of variation and the mean logarithmic deviation are given by, respectively,

$$\frac{\sum_{i=1}^N (y_i - \bar{y})^2 / N}{\bar{y}^2} \quad \text{and} \quad \frac{1}{N} \sum_{i=1}^N \ln \left( \frac{y_i}{\bar{y}} \right).$$

<sup>11</sup>Hoyne and Luttmer (2011) and Shaw (2014) adopt similar definitions of insurance and redistribution in the context of willingness to pay calculations. We note that the separation of the insurance and redistributive effects of taxes and transfers is contingent on our assumptions about individuals' knowledge of the earnings process at the start of the life cycle. In particular, the within-endowment inequality of lifetime earnings can only be interpreted as lifetime income risk if shocks are truly unforeseen. Likewise, the effect of taxes and transfers on the between-endowment inequality of lifetime income can only be interpreted as redistribution if individuals are fully informed about the expected consequences of their endowment at the beginning of the life cycle.

and pensions on income inequality.<sup>12</sup>

Table 4 summarizes our findings. Interestingly, although taxes and transfers are based on annual earnings, the first column of Table 4 shows that the tax-and-transfer system is strongly progressive on a lifetime basis. In particular, our calculations show that taxes and transfers eliminate 49% of the inequality of lifetime income (see, e.g., Brewer et al., 2012, and Bengtsson et al., 2016, for similar findings). This is an important result because: i) the inequality of lifetime earnings is substantial (the inequality of lifetime earnings is around two-thirds as large as the inequality of annual earnings, see Table 3); and ii) inequalities in lifetime earnings represent cross-individual differences that people cannot mitigate by saving and borrowing.<sup>13</sup>

The second and third columns of Table 4 explore this result. We see that taxes and transfers combined offset 54% of the within-endowment inequality of lifetime earnings, i.e., more than half of the inequality in lifetime earnings that arises from differences between the lifetime earnings of individuals with the same endowment is mitigated by taxes and transfers. Taxes and transfers together also offset a similar percentage (45%) of the between-endowment inequality of lifetime earnings. In other words, close to half of the inequality in lifetime earnings that arises from education and productive ability is offset by taxes and transfers. Together these results show that the tax-and-transfer system provides substantial insurance against lifetime earnings risk and is strongly redistributive on a lifetime basis. Finally, we note that since around half of the inequality in lifetime earnings is attributable to differences in individuals' endowments (see the first row of Table 4), the insurance and redistributive effects of taxes and transfers are similar in absolute terms.<sup>14,15</sup>

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<sup>12</sup>For a discussion about the distributional effects of pensions see, e.g., Conesa and Krueger (1999), Huggett and Parra (2010), Coronado et al. (2011), and Feldstein and Liebman (2002).

<sup>13</sup>The model also implies that taxes and transfers reduce the Gini coefficient for annual income by 0.188. This result aligns with previous studies, which have shown large mitigating effects of taxes and transfers on the inequality of annual income (see, e.g., Piketty and Saez, 2007, Heathcote et al., 2010, Fuchs-Schündeln et al., 2010, Wang et al., 2012, DeBacker et al., 2013, and Bengtsson et al., 2016).

<sup>14</sup>Our estimate of the share of the inequality of lifetime earnings that is explained by endowments is similar to that found by Huggett et al. (2011) (about 60%) and Storesletten et al. (2004) (about 50%). However, the estimated share is lower than that reported in Keane and Wolpin (1997), who attribute 90% of the inequality of lifetime earnings to endowments. Huggett et al. (2011) discuss how the different findings are related to the specification of the endowments and the modeled sources of risk.

<sup>15</sup>Tables SWA.3 and SWA.4 in Appendix VI show that the results reported in Table 4 continue to hold if inequality is measured using the squared coefficient of variation or the mean logarithmic deviation instead of the Theil index.

Table 4: Insurance and redistributive effects of the tax-and-transfer system

	Inequality of lifetime earnings and lifetime income ( $100 \times$ Theil index)			Ratio of between- endowment inequality to total inequality
	Total	Within-endowment	Between-endowment	
Earnings (Labor earnings+ interest income)	7.75	3.38	4.37	0.56
Income (Earnings–taxes+transfers)	3.96	1.56	2.41	0.61
Share of earnings inequality offset by the tax-and-transfer system	0.49	0.54	0.45	

*Notes:* All calculations are based on a sample of 10,000 income trajectories of individuals aged 20–59 years inclusive simulated from the estimated model (the notes to Table 3 describe how we use the estimated model to simulate income trajectories). The column headed ‘Total’ reports the inequality of lifetime earnings and lifetime income. The column headed ‘Within-endowment’ (‘Between-endowment’) reports the within-endowment (between-endowment) inequality of lifetime earnings and lifetime income. Taxes include a progressive tax on annual labor earnings, a progressive tax on annual interest income, and social security taxes for health and unemployment benefits (see Appendix II). Transfers include unemployment insurance, disability benefits, and social assistance (see Section 3.6).

We disaggregate the effects of the four programs that comprise the tax-and-transfer system (namely taxes, unemployment insurance, disability benefits, and social assistance). This allows us to understand which programs are most effective at reducing the inequality of lifetime income and to identify the specific programs that account for the insurance and redistributive effects of the tax-and-transfer system. A complication arises here because the effect of each program depends on the order in which the programs are considered. We deal with this issue by using the permutation-based method of Shorrocks (2013) to derive the contribution of each program to income inequality in a way that is robust to ordering effects. According to this method, the order-robust effect of a program on income inequality is obtained by calculating the program’s effect on income inequality for each of the twenty-four (i.e., four factorial) possible orders of the four programs and then averaging over the twenty-four possible program orders.

Table 5: Shares of lifetime earnings inequality offset by taxes and transfer programs

	Total	Within-endowment (Insurance)	Between-endowment (Redistribution)
Taxes	0.26	0.16	0.34
Unemployment insurance	0.03	0.03	0.02
Disability benefits	0.06	0.16	-0.01
Social assistance	0.14	0.19	0.10

*Notes:* All calculations are based on a sample of 10,000 income trajectories of individuals aged 20–59 years inclusive, simulated from the estimated model (the notes to Table 3 describe how we use the estimated model to simulate income trajectories). The column headed ‘Total’ reports the shares of the inequality of lifetime earnings that are offset by taxes, unemployment insurance, disability benefits and social assistance. The column headed ‘Within-endowment’ (‘Between-endowment’) reports the shares of the within-endowment (between-endowment) inequality of lifetime earnings that are offset by taxes, unemployment insurance, disability benefits and social assistance. Shares are calculated from inequality as measured using the Theil index.

The first column of Table 5 shows that taxes reduce the inequality of lifetime income by 26% while the three transfer programs combined (unemployment insurance, disability benefits, and social assistance) reduce the inequality of lifetime income by 23% (giving the aforementioned combined mitigating effect of the tax-and-transfer system on the inequality of lifetime income of 49%). Among the three transfer programs, social assistance is by far the most important program for reducing the inequality of lifetime income: social assistance offsets 14% of the inequality of lifetime earnings while unemployment insurance and disability benefits offset 3% and 6% of the inequality of lifetime earnings, respectively.<sup>16</sup>

The second and third columns of Table 5 report the effects of taxes and each of the three transfer programs on the within- and between-endowment inequality of lifetime income. These results, which we discuss in Sections 5.1.1-5.1.4, raise the following four questions about the insurance and redistributive effects of taxes and transfers. Why are taxes more effective at redistributing lifetime income than insuring lifetime earnings risk? Why do disability benefits fail to redistribute lifetime earnings? What drives the redistributive effect of unemployment insurance? What makes social assistance the most important transfer program for insuring lifetime earnings risk and redistributing lifetime income? We address each question in turn.

### 5.1.1 Why are taxes more effective at redistributing lifetime income than insuring lifetime earnings risk?

Table 5 shows that taxes reduce the between-endowment inequality of lifetime income by 34%. In contrast, taxes reduce the within-endowment inequality of lifetime income by only 16%. Thus, the insurance effect of taxes is around half of the size of the redistributive effect of

<sup>16</sup>Tables SWA.5 and SWA.6 in Appendix VI show that social assistance becomes more important as the inequality measure gives more weight to the bottom of the income distribution. Despite this, we find that the pattern of effects reported in Table 5 continues to hold when inequality is measured using the squared coefficient of variation or the mean logarithmic deviation instead of the Theil index.

taxes. Figure 4(a) explores the insurance effects of taxes in more detail by plotting the share of lifetime earnings paid in tax against lifetime earnings for each of the six endowment groups as shown in Figure 2. We find that within each endowment group the share of lifetime earnings paid in tax increases modestly with lifetime earnings. Consider, e.g., individuals endowed with fourteen years of education (high education) and high productive ability. Lifetime earnings for individuals in this group range from 700,000 euros to 3,000,000 euros. Individuals with the lowest lifetime earnings pay around 30% of their lifetime earnings in taxes while individuals with the highest lifetime earnings pay 38% of their lifetime earnings in taxes. In other words, while lifetime earnings increase more than 300% as we move from the lifetime poorest to the lifetime richest individuals the share of lifetime earnings paid in tax increases only 8 percentage points or 27%. A similar pattern holds for the other endowment groups.

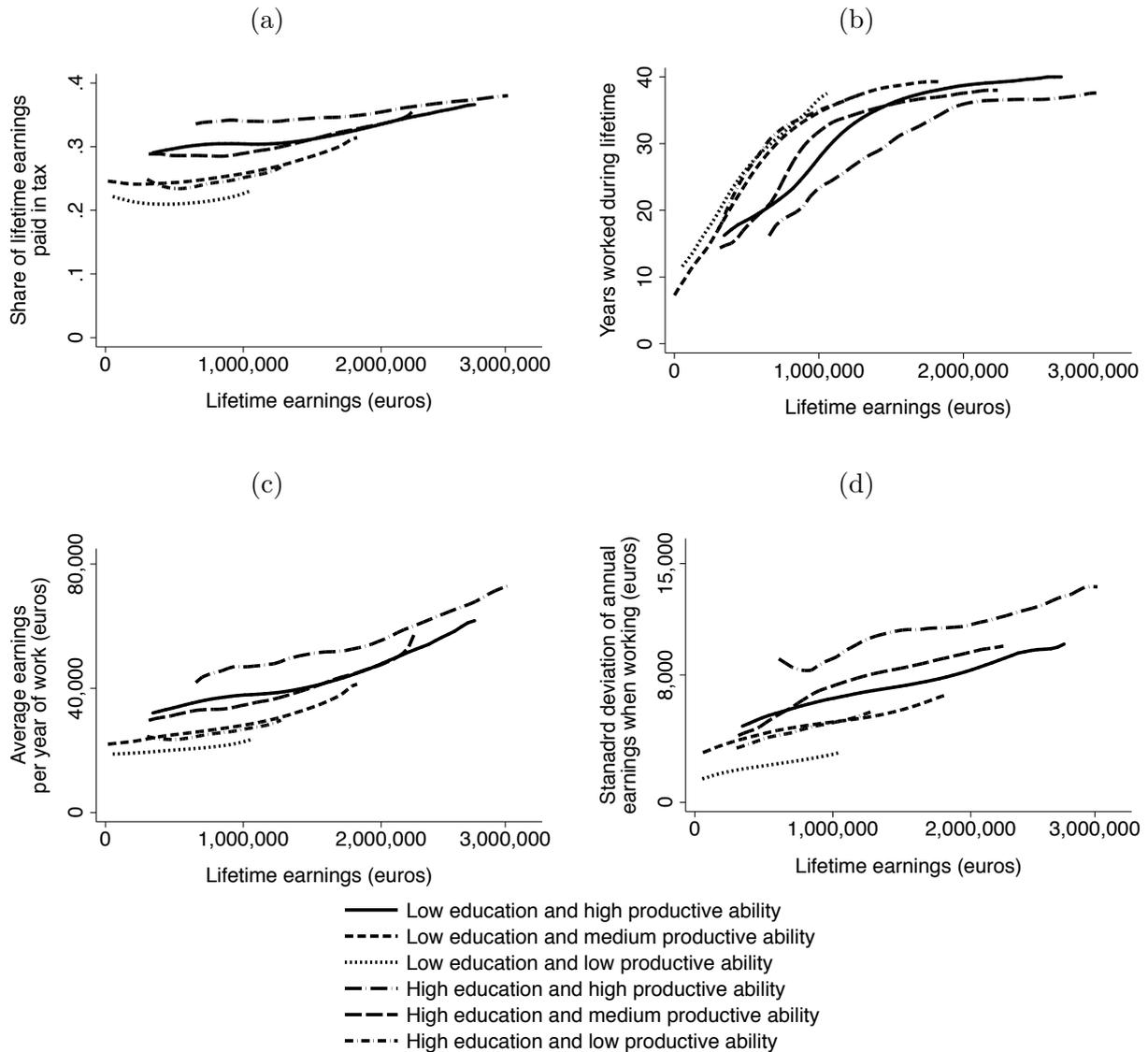
The key to understanding why taxes have a limited insurance effect is to note that annual taxes do not adjust for earnings in previous years of the individual's life. It follows that taxes based on annual earnings can not mitigate lifetime earnings differences that arise from differences in the number of years that individuals work during their lives. To help understand how differences in years worked during the life cycle contribute to our finding of a modest insurance effect of taxation Figure 4(b) shows average number of years worked during the life cycle against lifetime earnings for six of the thirty-three endowment groups that we model. Within each endowment group the number of years worked during the life cycle increases strongly with lifetime earnings. Aggregating over all endowment groups, we find that differences in years worked during the life cycle explain 70.7% of the within-endowment inequality of lifetime earnings (measured using the Theil index). This important role for years of work in determining lifetime earnings strongly limits the potential for annual taxes to provide insurance against lifetime earnings risk.

The inability of annual taxation to mitigate inequality in lifetime earnings due to differences in years worked during the life-cycle represents a disadvantage of annual taxation relative to multi-year or lifetime taxation, as proposed by Vickrey (1939, 1947). In contrast to annual taxation, a progressive tax on lifetime labor earnings would directly target all sources of within-endowment inequality of lifetime earnings and, therefore, would be more effective at insuring lifetime earnings risk.

Annual earning taxes may, however, provide insurance against the remaining 29.3% of the within-endowment inequality of lifetime earnings that is not due to differences in years worked during the life cycle. Insurance may operate through two channels. First, if average earnings per year of work increase with lifetime earnings among individuals with the same endowments then a progressive annual tax will translate into a progressive tax on lifetime earnings. Second, if the year-to-year variation in annual earnings across years of work increases with lifetime earnings for individuals in the same endowment group then, due to the convexity of the progressive annual tax function, annual taxes will again be progressive on a lifetime basis. Figures 4(c)–(d) show that both channels operate in practice. The increase in average earnings per year of work with lifetime earnings shown in Figure 4(c) reflects both the returns to experience and persistent wage

shocks. Similarly, both the wage returns to experience and persistent wage shocks contribute to the increase in the standard deviation of annual earnings with lifetime earnings shown in Figure 4(d). Further analysis in Appendix V shows that most of the insurance effect of annual taxes is driven by persistent wage shocks rather than returns to experience.

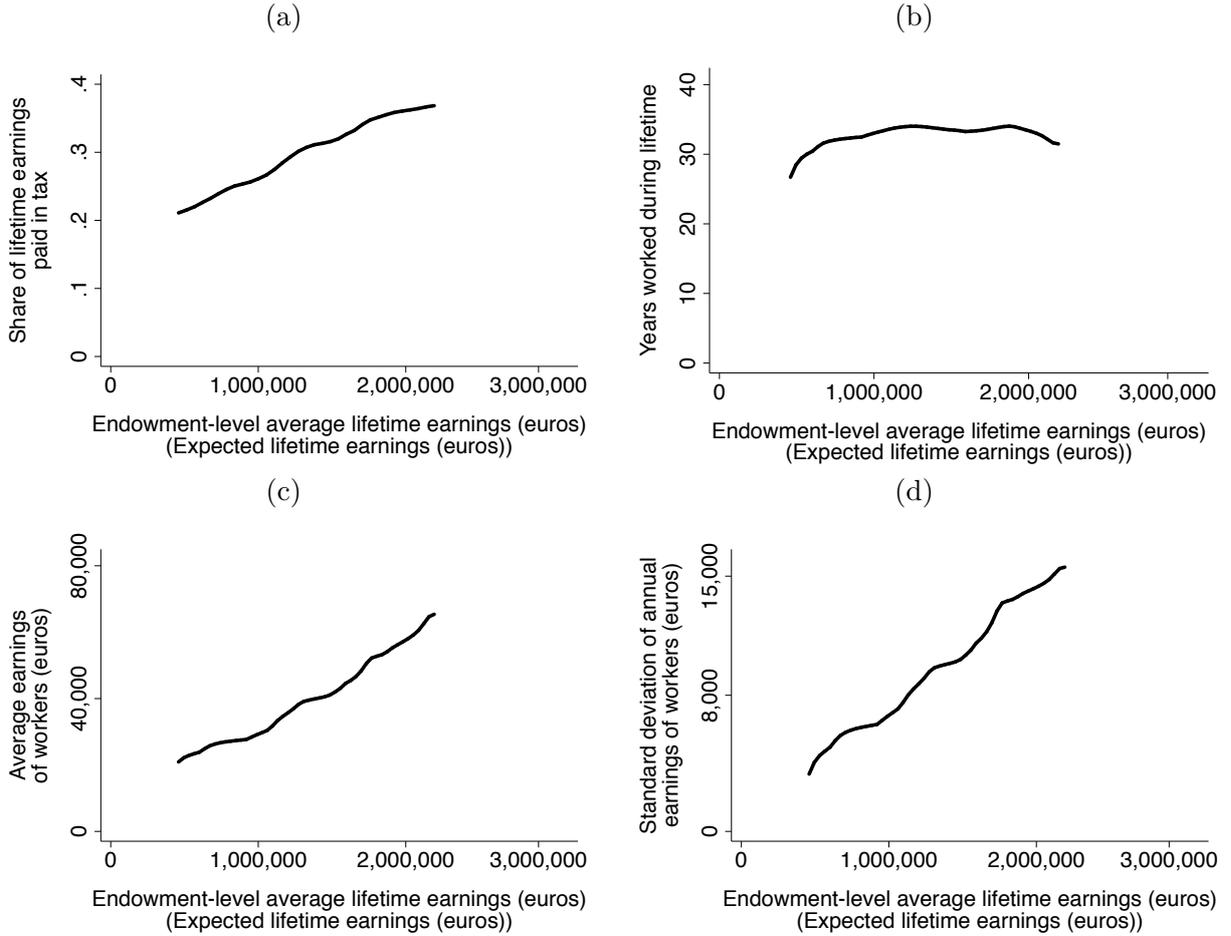
Figure 4: Insurance effects of taxation



*Notes:* Smoothed Nadaraya-Watson kernel regressions estimated using the simulated sample described in the notes to Table 4. ‘Low education’ refers eleven years of education and ‘high education’ refers to fourteen years of education.

Next we explore the redistributive effects of annual taxation and explain why annual taxation is highly effective at redistributing lifetime income between individuals with different endowments. Figure 5(a) shows that the share of lifetime earnings paid in tax increases strongly with the endowment-level average of lifetime earnings. Endowment-level average lifetime earnings vary from 600,000 euros to 2,400,000 euros. Individuals in the lowest-earning endowment group pay an average of 20% of their lifetime earnings in taxes while individuals in the highest earning endowment group earnings pay 38% of their lifetime earnings in taxes. A comparison of

Figure 5: Redistributive effect of taxation



*Notes:* Smoothed Nadaraya-Watson kernel regressions estimated using the simulated sample described in the notes to Table 4. All dependent variables are endowment-level averages.

Figure 4(a) and Figure 5(a) reveals that the relationship between lifetime taxation and lifetime earnings is much stronger between endowment groups than it is within endowment groups.

Three factors contribute to the large redistributive effect of annual taxes. First, annual taxes cannot address the between-endowment inequality in lifetime earnings that is due to differences across individuals in years of work, however, as shown in Figure 5(b), we find that essentially none of the between-endowment inequality in lifetime earnings is due to between-individual differences in years worked.<sup>17</sup> Second, a progressive annual tax will be more redistributive the more strongly endowment-level average earnings of workers increases with the endowment-level average of lifetime earnings. The high wage returns to education and productive ability that we find lead endowment-level average earnings of workers to increase strongly with the endowment-level average of lifetime earnings (see Figure 5(c)). Third, due to the convexity of progressive annual taxes, the redistributive effect of annual taxes increases with the year-to-year variability in worker's earnings. Figure 5(d) shows that workers with higher expected lifetime earnings

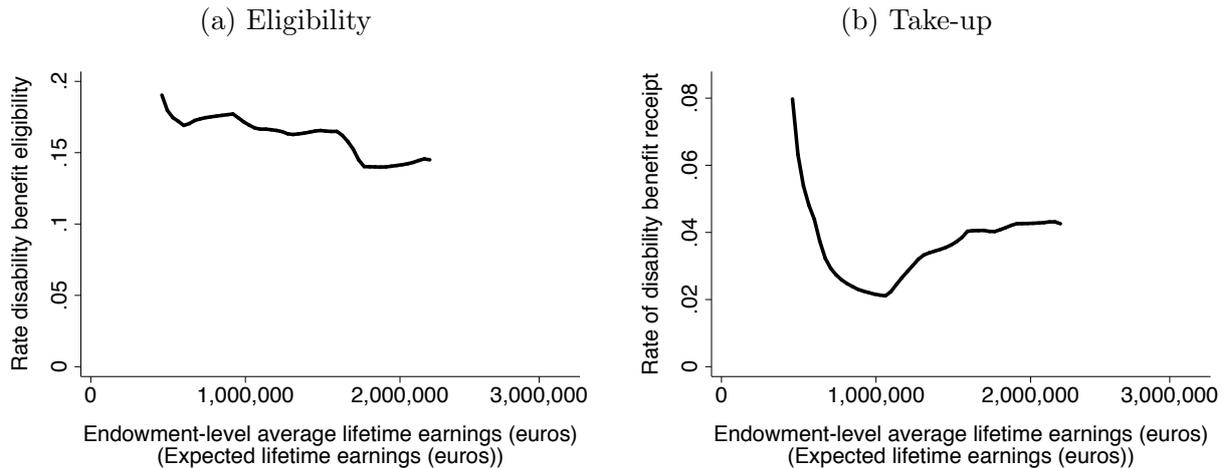
<sup>17</sup>Differences between endowment groups in the average number of years that individuals work during their lifetimes explains only 0.035% of the the between-endowment inequality in lifetime earnings.

have more variability in their earnings.<sup>18</sup>

### 5.1.2 Why do disability benefits fail to redistribute lifetime earnings?

Table 5 shows that disability benefits do not redistribute lifetime earnings between groups of individuals with different endowments of education and productive ability. Quantitatively, disability benefits increase the between-endowment inequality of lifetime income by one percentage point, which is a small effect compared to the 45% reduction in the between-endowment inequality of lifetime income achieved by the composite tax-and-transfer system.

Figure 6: Redistributive effect of disability benefits



*Notes:* Smoothed Nadaraya-Watson kernel regressions estimated using the simulated sample described in the notes to Table 4. The dependent variable in panel (a) is the endowment-level average of an individual-year-level indicator of eligibility for disability benefits (an individual is eligible for disability benefits in a given year if he is in bad health in that year). The dependent variable in panel (b) is the endowment-level average of an individual-year-level indicator of disability benefit receipt (an individual is defined to receive disability benefits in a given year if he has non-zero disability benefit income in that year).

At first sight, the absence of a redistributive effect for disability benefits is counterintuitive: given that education increases both expected lifetime earnings and the likelihood of being in good health (thereby decreasing the likelihood of eligibility for disability benefits), we expect disability benefits to reduce the inequality in lifetime income between individuals with high education (and therefore high expected lifetime earnings) and individuals with low education (and therefore low expected lifetime earnings). The reason that disability benefits fail to redistribute lifetime earnings is that, while the rate of eligibility for disability benefits decreases with expected lifetime earnings, the rate of disability benefit receipt is U-shaped (see Figure 6). The high take-up rate of disability benefits for individuals with low expected lifetime earnings reflects that the option value of future employment is relatively low for individuals with unproductive endowments. The increase in the take up rate with expected lifetime earnings for

<sup>18</sup>Given that the year-to-year variability of earnings increases with expected lifetime earnings, an annual tax may be more redistributive than an equally progressive tax on lifetime earnings.

individuals who expect to earn at least 1,000,000 euros in their lifetimes reflects a program interaction between social assistance and disability benefits. Recall, the value of the disability benefits increases with lifetime earnings while social assistance ensures individuals have a minimum annual income that does not depend on past earnings. It follows that as expected lifetime earnings increase so does the fraction of individuals who prefer disability benefits to social assistance. The wealth test for social assistance also contributes to the increase in disability benefit take-up with expected lifetime earnings because wealth tends to increase with expected lifetime earnings.

### **5.1.3 What drives the redistributive effect of unemployment insurance?**

Unemployment insurance is designed to provide short-term insurance against job loss, and is not generally considered to be a redistributive program. However, we find that unemployment insurance is mildly redistributive. Specifically, Table 5 shows that unemployment insurance eliminates two percent of the between-endowment inequality of lifetime income. This result is driven by the decrease in the risk of a job separation with education and the increase in health status with education, which further reduces the job separation risk (see Table 2). This pattern of employment risk leads unemployment insurance receipt to be concentrated among individuals with low expected lifetime earnings. In particular, in our simulated sample, individuals with expected lifetime earnings below 500,000 euros receive unemployment insurance for an average of 2.6 years between age 20 years and age 60 years, while individuals with expected lifetime earnings above 1,500,000 euros receive unemployment insurance for an average of 0.6 years during the same time period.

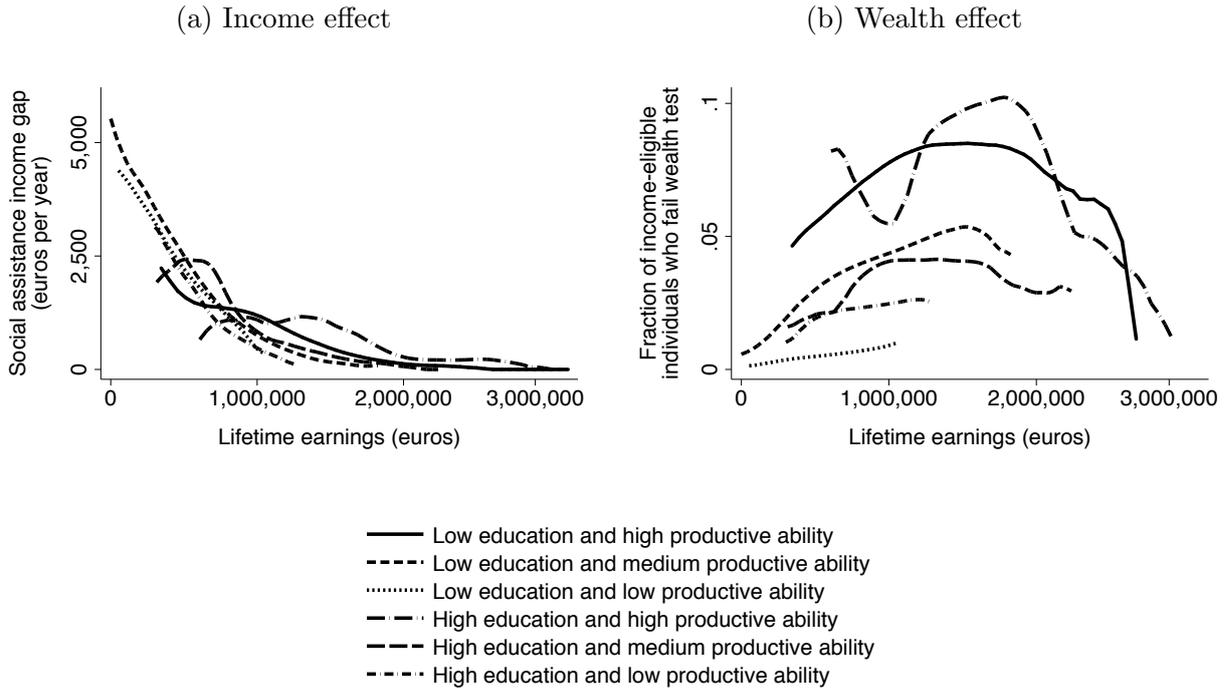
### **5.1.4 What makes social assistance the most important transfer program for insurance and redistribution?**

Among the three transfer programs, social assistance has by far the largest effect on the inequality of lifetime income: Table 5 shows that social assistance eliminates 14% of the inequality of lifetime income, while unemployment insurance and disability benefits eliminate, respectively, 3% and 6% of the inequality of lifetime income. Table 5 further shows that social assistance is important for insuring lifetime earnings risk and redistributing lifetime income. In particular, social assistance offsets 19% of the within-endowment inequality of lifetime earnings and mitigates 10% of the between-endowment inequality of lifetime earnings. The insurance and redistributive effects of social assistance exceed those of unemployment insurance and disability benefits.

To understand why social assistance has large insurance and redistributive effects we must consider the rules that are used to calculate social assistance. As explained in Section 2.1, social assistance makes up the difference between an individual's income from all other sources and the minimum income guarantee. The minimum income guarantee decreases with wealth and is zero for individuals who are sufficiently wealthy. We explore the effects of social assistance by separating the income-based determinants of social assistance from the effect of the wealth-

based adjustment to the minimum income guarantee. In particular, we learn about the income-based determinants of social assistance by studying the ‘social assistance income gap’, defined as the difference between the non-wealth-adjusted minimum income guarantee and individual’s annual income before social assistance. We parse out the effect of the wealth-based social assistance rules by studying how often the wealth-based adjustment to the minimum income guarantee reduces the social assistance received by income-eligible individuals to zero, i.e., we study the fraction of income-eligible individuals who fail the social assistance wealth test.

Figure 7: Insurance effect of social assistance



*Notes:* Smoothed Nadaraya-Watson kernel regressions estimated using the simulated sample described in the notes to Table 4. The dependent variable in the regressions illustrated in panel (a) is an individual-year-level variable that is equal to the difference between the non-wealth-adjusted annual minimum income guarantee and an individual’s annual income before social assistance (this variable is censored at zero and thus is equal to zero if the individual’s annual income before social assistance is greater than the non-wealth-adjusted annual minimum income guarantee). The dependent variable in the regressions illustrated in panel (b) is an individual-year-level indicator for an individual’s annual social assistance income being reduced to zero by the wealth-based adjustment to the annual minimum income guarantee (these regression are estimated using only individual-year observations where the individual was eligible for social assistance on the basis of income). ‘Low education’ refers to eleven years of education and ‘high education’ refers to fourteen years of education.

We first consider the insurance effect of social assistance. We focus on the same six endowment groups as considered in Figure 2. Figure 7(a) shows that within each endowment group the social assistance income gap decreases rapidly with lifetime earnings, indicating that the income-based social assistance rules make social assistance an effective insurance device. This occurs because the income-based rules for social assistance focus the benefit on individuals with low annual income from other sources and, among individuals with the same endowment, those with low lifetime earnings experience many years with low income, i.e., low income status is highly persistent.

Figure 7(b) shows the fraction of income-eligible individuals who fail the social assistance

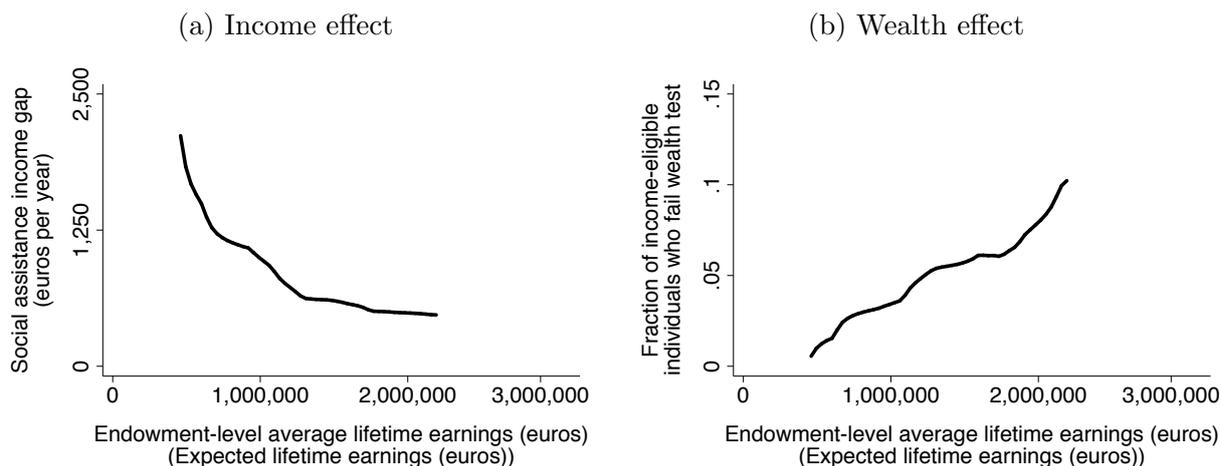
wealth test against lifetime income for six of the thirty-three endowment groups that we model. Overall, within each endowment group, there is a hump-shaped pattern with individuals with highest and lowest lifetime earnings being the least likely to fail the wealth test and individuals with intermediate lifetime earnings failing the wealth test most often. Individuals with high lifetime earnings fail the wealth test relatively infrequently because individuals with relatively high lifetime earnings typically have annual incomes (excluding social assistance) that are below the non-wealth adjusted minimum income guarantee only when they are young. These young individuals generally have low wealth and thus actually receive social assistance. Meanwhile individuals with intermediate lifetime earnings typically have annual incomes (excluding social assistance) that are below the non-wealth adjusted minimum income guarantee at several difference times during the life cycle, including at older ages when they have accumulated sufficient wealth to make themselves ineligible for social assistance. Individuals with the lowest lifetime earnings rarely work and therefore are unlikely to have accumulated sufficient wealth to make them ineligible for social assistance.

From Figure 7(b) it is unclear whether the wealth-testing of social assistance increase or decreases the insurance effect of social assistance. Further calculations show that eliminating the wealth-based adjustment to social assistance benefits increases the share of within-endowment inequality in lifetime earnings that is offset by social assistance from 19% (see Table 5) to 20%, i.e., a 5% increase in effectiveness. We note that, although wealth-testing social assistance reduces the insurance effect of social assistance, wealth-testing reduces the financial cost of providing social assistance. This raises the question of whether there is an alternative way of wealth-testing social assistance that limits the costs of providing social assistance without attenuating the insurance effects of the program. We argue that the insurance effect of social assistance may be improved without additional costs by switching to a lifetime wealth test that requires individuals with high wealth later in life to repay any social assistance received when younger. Since wealth reflect strong prior earnings, the lifetime wealth test would recoup social assistance expenditures from individuals with high lifetime earnings, thereby improving the insurance effect of social assistance.

We now turn to the redistributive effect of social assistance. We again separate the effects of the income-based and wealth-based determinants of social assistance. Figure 8(a) shows that the social assistance income gap is modest, only around 500 euros per person per year, for individuals with expected lifetime earnings above 1,000,000 euros. However, the social assistance income gap increases sharply as expected lifetime earnings decrease below this level, and reaches over 2,000 euros per person per year for individuals with the lowest level of expected lifetime earnings. This pattern implies that the income-based rules for social assistance are strongly redistributive. Intuitively, social assistance targets the incomes of individuals with low expected lifetime incomes because the income-based rules for social assistance focus the benefit on individuals with low annual income (before social assistance) and individuals with low expected lifetime earnings tend to experience many years of low income during their lives. Figure 8(b) shows an upwards sloping relationship between ineligibility for social assistance on

the basis of wealth and expected lifetime earnings, showing that the wealth-testing of social assistance increases the redistributive effect of the program. Quantitatively, we find that eliminating the wealth test for social assistance reduces the redistributive effect of social assistance by 1%. While the wealth test for social assistance makes the program more redistributive, switching to a lifetime wealth test may increase the redistributive effect of this program because most of the social assistance expenditures recouped under the lifetime wealth test would come from individuals in endowment groups with high expected lifetime earnings.

Figure 8: Redistributive effect of social assistance



*Notes:* Smoothed Nadaraya-Watson kernel regressions estimated using the simulated sample described in the notes to Table 4. Dependent variables are endowment-level averages of the individual-year-level variables defined in the notes to Figure 7.

## 6 Insurance of lifetime employment and health risks

Finally, we show how employment risk and health risk affect the inequality of lifetime earnings and we explore how taxes and transfer programs provide insurance against these risks. This analysis leverages the estimated life-cycle model in two respects. First, we use the model to learn how specific changes in employment and health risks affect the inequality of lifetime earnings. This contrasts with our earlier decomposition-based analysis, which pooled together all sources of lifetime earnings risk. Second, we use the model to study how taxes and transfer programs insure employment and health risks while accounting for the self-insurance that individuals obtain by optimally adjusting their labor supply and savings behavior in response to changes in the risks that they face.

We consider four risk environments: a baseline environment and three counterfactual risk environments in which individuals face an increased risk of adverse employment or health events. In the baseline environment, health shocks, job offers, and involuntary job separations occur at the rates given by the estimated life-cycle model (see Figure 3 and Table 2). In the first counterfactual environment employed individuals face an increased risk of being subject to an involuntary job separation, in the second counterfactual environment unemployed individuals face a decreased risk of receiving a job offer, and in the third counterfactual environment

individuals face an increased risk of bad health shocks. In particular, each counterfactual environment is defined by scaling the relevant risk probability to make the employment rate one percentage point lower than the baseline rate, e.g., in the first counterfactual environment the involuntary job separation probability is scaled up to make the employment rate one percentage point lower than the baseline rate. The three counterfactual environments, therefore, feature different employment and health risks but the same employment rate.

Table 6: Employment risk and health risk environments

	Baseline	Increased job separation risk	Decreased job offer rate	Increased risk of bad health shocks
Employment rate	0.83	0.82	0.82	0.82
Average unemployment spells per person	1.16	1.24	0.85	1.16
Average unemployment spell duration (years)	3.09	3.10	3.57	3.14
Rate of bad health	0.16	0.16	0.16	0.20
Average bad health spells per person	1.01	1.01	1.01	1.29
Average bad health spell duration (years)	6.28	6.28	6.28	6.33

*Notes:* Calculations for all three risk environments are based on samples of 10,000 life-cycle trajectories of individuals aged 20–59 years inclusive, simulated from the estimated model (the notes to Table 3 describe how we use the estimated model to simulate employment trajectories). Results for the baseline environment were calculated using the estimated parameter values. Results for the environment with increased job separation risk were obtained by proportionally increasing the estimated job separation probabilities to reduce the employment rate by one percentage point from the baseline rate. Results for the environment with the decreased job offer rate were obtained by proportionally decreasing the estimated job offer probabilities to reduce the employment rate by one percentage point from the baseline rate. Results for the environment with the increased risk of bad health shocks were obtained by proportionally increasing the estimated probability of a transition from good to bad health status to reduce the employment rate by one percentage point from the baseline rate.

Table 6 summarizes employment and health outcomes in the four risk environments. The employment rate is 83% in the baseline environment and, by construction, 82% in each of the counterfactual environments. The increase in job separation risk increases the average number of unemployment spells per person from 1.16 to 1.24 but hardly affects the average unemployment spell duration. In contrast, the decrease in job offer rate increases the average unemployment spell duration from 3.09 years to 3.57 years; at the same time, the average number of unemployment spells per person decreases to 0.85, reflecting compositional change in the pool of employed individuals. The increased risk of bad health shocks increases the rate of bad health from 16% to 20% and increases the average number of bad health spells per person from 1.01 to 1.29.

The first row of Table 7 shows that the increase in job separation risk, the decrease in the job offer rate, and the increase in the risk of bad health shocks cause sizable increases in the within-endowment inequality of lifetime earnings. Relative to the baseline environment, the within-endowment inequality of lifetime earnings increases by around 5% in response to the

Table 7: Insurance of employment risk and health risk

	Within-endowment inequality in baseline	$\Delta$ Within-endowment inequality		
		Increased job separation risk	Decreased job offer rate	Increased risk of bad health shocks
Lifetime earnings (Labor earnings+ interest income)	3.38	0.18 [5%]	0.64 [19%]	0.39 [12%]
Lifetime income (Earnings–taxes+transfers)	1.56	0.06 [4%]	0.28 [18%]	0.14 [9%]
Share of extra within- endowment inequality offset by the tax-and-transfer system		0.66	0.56	0.65

*Notes:* Inequality is measured using (100 $\times$ ) the Theil index. ‘ $\Delta$  Within-endowment inequality’ is the increase in within-endowment inequality from the baseline environment. The percentage increases in inequality from the baseline are shown in brackets. the within-endowment inequality of lifetime earnings increases by around Also see notes to Table 6.

increase in job separation risk and increases by 19% in response to the decrease in the job offer rate. The increase in the risk of bad health shocks, meanwhile, increases the within-endowment inequality of lifetime earnings by 12%. The relatively large increase in inequality associated with the decrease in the job offer rate reflects that this risk increase extends unemployment durations, thereby depressing the lifetime earnings of individuals at the bottom of the distribution of lifetime earnings.

Table 7 also shows that 56–66% of the increase in lifetime earnings risk that arises from increased employment risk is mitigated by the tax-and-transfer system while the remaining 44–33% of the extra lifetime earnings risk passes through into inequality in lifetime income. The tax-and-transfer system therefore insures the majority of the additional earnings risk associated with increases in employment risk. The tax-and-transfer system provides a similar level of insurance against health shocks, specifically 65% of the extra within-endowment inequality of lifetime earnings associated with an increase in the risk of bad health shocks is mitigated by the tax-and-transfer system.<sup>19</sup>

Table 8 explores the insurance effect of the tax-and-transfer system in more detail by separating the effects of taxes and transfers (unemployment insurance, disability benefits, and social

<sup>19</sup>Tables SWA.7 and SWA.8 in Appendix VI explore the robustness of the results in Table 7 to measuring inequality using the squared coefficient of variation and the mean logarithmic deviation instead of the Theil index. Irrespective of the measure of inequality, the tax-and-transfer system offers essentially equal amounts of insurance against the two different employment risks. The amount of insurance increases as we move to inequality measures that give more weight to the bottom of the income distribution, reflecting that the tax-and-transfer system is relatively effective at mitigating increases in the inequality of lifetime earnings among the lifetime poor.

Table 8: Shares of additional within-endowment lifetime earnings inequality offset by taxes and transfer programs

	Increased job separation risk	Decreased job offer rate	Increased risk of bad health shocks
Taxes	0.07	0.11	0.08
Unemployment insurance	0.06	-0.01	0.02
Disability benefits	0.23	0.13	0.36
Social assistance	0.30	0.33	0.19

*Notes:* Inequality is measured using the Theil index. Also see notes to Table 6.

assistance). We find that transfers rather than taxes are primarily responsible for insurance that the tax-and-transfer system provides against employment and health shocks: irrespective of the source of the increase in inequality, taxes mitigate 7–11% of the increase in the within-endowment inequality of lifetime earnings. Meanwhile, transfer programs offset around half of the extra within-endowment inequality in lifetime earnings. Interestingly, the relative importance of each of the three transfer programs—unemployment insurance, disability benefits and social assistance—depends on the source of the additional within-endowment inequality of lifetime earnings.

In more detail, unemployment insurance mitigates 6% of the increase in the within-endowment inequality of lifetime earnings that arises from an increase in job separation risk. In contrast this program has a small negative effect (-1%) on the extra within-endowment inequality that arises from a decrease in the job offer rate. This pattern reflects that, since unemployment insurance provides income replacement only during the first year of an unemployment spell, this program is well placed to mitigate the effects of job separation risk, which affects the frequency but not the duration of unemployment. Since unemployment insurance does not provide long-term income replacement, it is not effective at mitigating the effects of lifetime earnings risk that is driven by a decrease in the job offer rate, which increases the average duration of unemployment spells.

Disability benefits mitigate 36% of the increase in the within-endowment inequality of lifetime earnings that arises from an increase in the risk of bad health shocks. This large effect shows the importance of disability benefits for insuring lifetime health risk. Two factors prevent disability benefits from being even more effective at insuring lifetime health risk. First, the amount of insurance that disability benefits provide is limited because disability benefits only partially replace lost earnings. Second, although bad health status qualifies an individual for disability benefits, some eligible individuals do not take up the benefits because doing so precludes future employment. We also note that disability benefits are more effective at insuring health risk than employment risk, however, the insurance against employment risk is important: disability benefits mitigate 13–23% of the within-endowment increase in inequality that arises from increased employment risk. This pattern reflects that some bad-health indi-

viduals who experience a job separation or who are unemployed and without a job offer choose to claim disability benefits. Since individuals with long periods of unemployment in their work history are not entitled to generous disability benefits, disability benefits are less effective at insuring earnings risk that arises from a decrease in the job offer rate than they are at insuring earnings risk that is generated by the increase in job separation risk.

Social assistance is an effective program for providing insurance against job separation risk, job offer risk, and health risk. However, social assistance is particularly effective at providing insurance against earnings risk that arises from a decrease in the job offer rate. This reflects that social assistance is a permanent transfer and thus is effective at mitigating the lifetime income consequences of the increase in unemployment durations that arises from a decrease in the job offer rate.<sup>20</sup>

## 7 Conclusion

The tax-and-transfer system may redistribute lifetime earnings between individuals with different skill endowments, thereby counteracting the inequality in lifetime earnings that is due to individual differences that originate early in life. The tax-and-transfer system may also mitigate differences in lifetime earnings that arise from unpredictable events that individuals experience during their lifetimes, such as job loss, difficulty in finding employment, or changes in health status. That is, taxes and transfers may provide individuals with insurance against lifetime earnings risk. In this paper, we have shown how the tax-and-transfer system insures lifetime earnings risk and how it redistributes lifetime earnings between individuals with different skill endowments.

Our results on redistribution show that the tax-and-transfer system absorbs around half of the inequality in lifetime earnings due to differences in skill endowments. This finding is relevant to discussions of the inequality-increasing effects of skill-biased technological change (e.g., Bekman et al., 1998, Autor et al., 2003). In particular, to the degree that skill-biased technological change increases earnings inequality by raising the returns to endowments, our results suggest that only half of the extra inequality in lifetime earnings associated with skill-biased technological change will pass through into inequality in lifetime income. We also find that the tax-and-transfer system offers considerable insurance against lifetime earnings risk. In particular, the tax-and-transfer system insures around 60% of the inequality in lifetime earnings that can be attributed to employment and health shocks. The insurance function of the tax-and-transfer system operates mainly through social assistance and disability benefits.

Our findings suggest two possible reforms to the tax-and-transfer system that may improve its lifetime properties. First, the lifetime insurance effect of the tax-and-transfer system may be increased by switching to a system of lifetime taxation. While progressive annual taxation

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<sup>20</sup>Tables SWA.9 and SWA.10 in Appendix VI show that the results in Table 8 to are qualitatively robust to measuring inequality using the squared coefficient of variation and the mean logarithmic deviation instead of the Theil index.

offers limited insurances against lifetime earnings risk, a progressive tax on lifetime earnings, as discussed by Vickrey (1939, 1947), would directly target unexpected differences in lifetime earnings and, therefore, would provide individuals with more insurance against lifetime earnings risk. Second, the lifetime insurance and redistributive effects of social assistance may be increased, without additional financial costs, by replacing the annual wealth test with a lifetime wealth test that requires individuals with high wealth later in life to repay any social assistance received when younger.

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# **Supplementary Web Appendix**

(Intended for Online Publication)

## Appendix I: Pensions

Individuals in old-age retirement (i.e., individuals who retired at age 63 or above in good health) receive pension benefits each year for the remainder of their lives. The annual pension benefit received by an individual who entered old-age retirement at age  $R$  is given by:

$$\text{Pension} = \alpha \times \bar{W}_R \times \text{PenPenalty}_R \times \text{Exper}_R, \quad (13)$$

where  $\alpha$  is a parameter that controls the generosity of pension benefits,  $\bar{W}_R$  is the individual's annual pension-benefit-eligible labor earnings averaged over all years of employment prior to retirement,  $\text{Exper}_R$  is the individual's experience (in years) at retirement, and  $\text{PenPenalty}_R$  is a penalty that reduces the individual's annual pension by 3.6% for each year that he retired before the age of 65 years. Only annual labor earnings below 72,374 euros are considered when calculating pension benefits. The taxation of pension benefits is described in Appendix II.

## Appendix II: Taxes

Annual labor earnings above an exemption threshold of 8,652 euros are subject to a labor earnings tax. The labor earnings tax function is a smooth progressive function of taxable annual labor earnings with a marginal tax rate that ranges from 15% to 42%. Annual interest income above an exemption threshold of 801 euros is taxed at a constant marginal rate of 25%. Individuals pay a further tax (Solidaritaetszuschlag) of 5.5% of their tax liability on labor earnings and interest income. Individuals also pay a social security tax for health, unemployment and pension benefits. The social security tax is a flat rate tax of 18.2% (7.35% for health benefits, 1.5% for unemployment benefits, and 9.35% for pension benefits) on labor earnings below a cap of 74,400 euros per year.

Fifty percent of annual pension benefit income in excess of an exemption threshold of 17,306 euros is taxed on the same basis as taxable labor earnings. We account for the taxation of pension benefits, along with all other taxes, when estimating the model and when using the estimated model to simulate datasets. However, because we focus on individuals younger than age 60 years, the taxation of pension benefits does not affect the decompositions presented in Sections 5 and 6.

## Appendix III: Estimation sample

The estimation sample is an unbalanced annual panel sample of men from years 2004–2016 of German Socio-Economic Panel (SOEP). The estimation sample excludes individuals younger than 20 years or older than 65 years, individuals in education, East Germans, the self-employed and civil servants. Table SWA.1 provides definitions and descriptive statistics for the variables used in the analysis.

Table SWA.1: Descriptive statistics for the SOEP sample

Variable	Observations	Mean	Minimum	Maximum
Age (years)	20,843	45.760	20	64
Employed	20,843	0.874	0	1
Unemployed	20,843	0.074	0	1
Retired (disability-based or old-age retirement)	20,843	0.052	0	1
Education (years)	20,843	12.362	7	18
Health	20,843	0.832	0	1
Involuntary job separation	20,843	0.022	0	1
Experience (years)	20,843	22.474	0	49
Wage (euros per hour)	18,225	19.993	8.5	47.01
Wealth (euros)	20,843	56,978	0	660,000

*Notes:* Individuals working at least 20 hours per week are classified as employed. The small number of men working fewer than 20 hours per work are classified as unemployed. Median hours of work per week for individuals who are employed is 40. Years of education includes time spent in formal education and occupational training. Health is an indicator of good health, defined as neither being officially disabled nor assessing own health as “bad” or “very bad”. Involuntary job separations are defined as transitions to unemployment due to the end of a fixed term contract, dismissal or firm closure and transitions into unemployment when the individual has bad health. Experience is defined as years spent in employment. Wage is the pre-tax hourly wage (wages are only observed for individuals in employment). Wealth is calculated from information about the net value of financial and real assets that were collected in the 2007 SOEP survey and information about savings that was collected in every SOEP survey. Wealth is left censored at zero and right censored at 660,000 euros. Wages and wealth are expressed in year 2016 prices.

## Appendix IV: Estimation

In Appendix IV.1 we explain how we approximate the value function, in Appendix IV.2 we present the likelihood function, and in Appendix IV.3 we describe how we maximize the likelihood function.

### Appendix IV.1: Value function approximation

We derive analytic expressions for the value function that appears in (9), starting from the following choice-specific value functions:

$$V_t(c_{i,t}, l_{i,t}, \mathbf{s}_{i,t}) = U(c_{i,t}, l_{i,t}) + \beta E_t[V_{t+1}(\mathbf{s}_{i,t+1}) | \mathbf{s}_{i,t}, c_{i,t}, l_{i,t}] \quad \text{for } t = 20, \dots, T, \quad (14)$$

where  $E_T[V_{T+1}(\mathbf{s}_{i,T+1}) | \mathbf{s}_{i,T}, c_{i,T}, l_{i,T}] = 0$  (since period  $T$  is the last period of the individual's life). Let  $\mathbf{x}_{i,t}$  denote the age- $t$  state variables excluding the preference shocks. We decompose the choice-specific value functions into a systematic component and a random component, which corresponds to the preference shock:

$$V_t(c_{i,t}, l_{i,t}, \mathbf{s}_{i,t}) = \bar{V}_t(c_{i,t}, l_{i,t}, \mathbf{x}_{i,t}) + \epsilon_{i,t}(c_{i,t}, l_{i,t}) \quad \text{for } t = 20, \dots, T. \quad (15)$$

Given the distributional assumptions about preference shocks (see Section 3.7), we have the following analytic expression for the expected age  $t + 1$  value function:

$$E_t[V_{t+1}(\mathbf{s}_{i,t+1}) | \mathbf{s}_{i,t}, c_{i,t}, l_{i,t}] = \sum_{\mathbf{x}_{t+1}} \log \left( \sum_{\{c,l\} \in \mathbb{D}(\mathbf{x}_{t+1})} \exp(\bar{V}_{t+1}(c, l, \mathbf{x}_{i,t+1})) \right) \times q(\mathbf{x}_{t+1} | \mathbf{x}_t, c_{i,t}, l_{i,t}) \quad \text{for } t = 20, \dots, T - 1, \quad (16)$$

where  $q(\mathbf{x}_{t+1} | \mathbf{x}_t, c_{i,t}, l_{i,t})$  denotes the joint probability mass function of the state variables  $\mathbf{x}_{i,t+1}$  conditional on the state variables  $\mathbf{x}_{i,t}$  and conditional on the individual's consumption and labor supply outcome at age  $t$  (since the choice set does not depend on preference shocks,  $\mathbb{D}(\mathbf{x}_t) \equiv \mathbb{D}(\mathbf{s}_t)$ ).

We approximate the value function using recursive interpolation, working backwards from age  $T$  (see Keane and Wolpin, 1994). In more detail, for each age, we evaluate the value function at set of grid points. The evaluation grid includes all possible values of health, labor supply outcome in the previous year, and unobserved productive type. The evaluation grid also includes 8 values of wealth (0, 10000, 20000, 30000, 50000, 100000, 150000, 700000), 6 values of experience (0, 10, 20, 30, 40, 50), 4 values of education (7, 11, 12, 18), 5 values of lagged log(hourly wage) (2, 2.5, 3, 3.5, 4), and 5 values of draws from the standard normal distribution for the calculation of the wage shocks (-2, -1, 0, 1, 2), giving a total of 57,600 grid points. We then use a linear interpolation function to predict the value function at values of the state variables that are not included in the evaluation grid. The results are insensitive to increasing in the number grid points and changing the interpolation method.

## Appendix IV.2: Likelihood function

The log likelihood function is given by:

$$\mathcal{L}(\boldsymbol{\alpha}, \boldsymbol{\phi}, \boldsymbol{\psi}) = \sum_{i=1}^N \log \left\{ \sum_{e=1}^2 1(e = E) \sum_{j=1}^3 \rho_{j,E} \prod_{t=\underline{t}_i}^{\bar{t}_i} P(l_{i,t} | \eta_i = \eta_j, \boldsymbol{\alpha}, \boldsymbol{\phi}, \boldsymbol{\psi}) f(\text{Wage}_{i,t}^* | \eta_i = \eta_j, \boldsymbol{\psi}) \right\}, \quad (17)$$

where  $N$  denotes the number of individuals in the sample,  $\boldsymbol{\alpha} = \{\alpha_1, \alpha_2\}$  denotes the parameters of the utility function,  $\boldsymbol{\phi} = \{\phi_1^s, \dots, \phi_6^s, \phi_1^o, \dots, \phi_6^o\}$  denotes the parameters of the job separation and job offer probabilities,  $\boldsymbol{\psi} = \{\delta, \psi_1, \dots, \psi_6, \eta_1, \eta_2, \eta_3, \rho_{11}, \rho_{12}, \rho_{21}, \rho_{22}, \sigma_\mu^2, \sigma_\nu^2\}$  denotes the parameters of the wage equation (including the variances of wage measurement error and wage shocks),  $\underline{t}_i$  and  $\bar{t}_i$  denote individual  $i$ 's age when we entered and when he left the sample, respectively,  $P(l_{i,t} | \eta_i = \eta_j, \boldsymbol{\alpha}, \boldsymbol{\phi}, \boldsymbol{\psi})$  denotes the probability of the individual's labor supply outcome at age  $t$ , conditional on being productive ability type  $j$ , and  $f(\text{Wage}_{i,t}^* | \eta_i = \eta_j, \boldsymbol{\psi})$  is the density of the sample wage observation, again conditional on the individual's productive ability type (recall, the sample log wage is equal to the actual log wage plus a normally distributed measurement error). To simplify notation, we set  $f$  equal to one for unemployed and retired individuals, for whom the wage is not observed.

Intuitively, each individual contributes to the likelihood the joint probability of his labor supply outcomes and sample wage values (when observed) over the years that he was in the sample. Conditional on an individual's productive ability type, labor supply outcomes and wages are independent over years. Given that the individual's productive ability type is unobserved to the econometrician, the individual's contribution to the sample likelihood is obtained by taking the product over the individual's conditional annual likelihood contributions and then integrating over the distribution of productive ability.

In the likelihood function,  $P(l_{i,t} | \eta_i = \eta_j, \boldsymbol{\alpha}, \boldsymbol{\phi}, \boldsymbol{\psi})$  denotes the probability of the individual's labor supply outcome at age  $t$ , conditional on his productive ability type. To calculate this probability, we start with joint probability of a consumption choice  $m$ , and the individual's labor supply outcome, conditional on the individual's productive ability type and his job offer and job separation status (which affects the choice set,  $\mathbb{D}(\mathbf{x}_{i,t})$ ):

$$P(m, l_{i,t} | \eta_i = \eta_j, \text{JO}_{i,t}, \text{JS}_{i,t}, \boldsymbol{\alpha}, \boldsymbol{\phi}, \boldsymbol{\psi}) = \frac{\exp(\bar{V}_t(m, l_{i,t}, \mathbf{x}_{i,t}))}{\sum_{\{c,l\} \in \mathbb{D}(\mathbf{x}_{i,t})} \exp(\bar{V}_t(c, l, \mathbf{x}_{i,t}))}, \quad (18)$$

where  $\bar{V}_t()$  is the systematic component of the choice-specific value function given by (15). Summing over the possible consumption choices and integrating over the distributions of job offers and job separations gives the required probability:

$$P(l_{i,t} | \eta_i = \eta_j, \boldsymbol{\alpha}, \boldsymbol{\phi}, \boldsymbol{\psi}) = \sum_m \int \int P(m, l_{i,t} | \eta_i = \eta_j, \text{JO}_{i,t}, \text{JS}_{i,t}, \boldsymbol{\alpha}, \boldsymbol{\phi}, \boldsymbol{\psi}) dF(\text{JO}_{i,t}) dF(\text{JS}_{i,t}), \quad (19)$$

where  $F(\text{JO}_{i,t})$  and  $F(\text{JS}_{i,t})$  denote the cumulative distribution functions for job offers and involuntary job separations, respectively.

### Appendix IV.3: Maximization of the likelihood function

We maximize the likelihood function using a maximum likelihood procedure that utilizes the numerical gradient and the BHHH Hessian (Berndt et al., 1974). The health transition probabilities and the parameters of the separation probabilities ( $\phi_1^s, \dots, \phi_6^s$ ) are estimated separately in a first step and, then, taken as given in the estimation of the full model. Furthermore, in order to obtain good starting values for the wage process and the type probabilities, we estimate the wage process together with the type probabilities separately first and, subsequently, use these estimates as starting values in the estimation of the full model. Based on these starting values as well as starting values for the utility function and the parameters of the offer probabilities that are within a reasonable range, the ML procedure converges quickly.

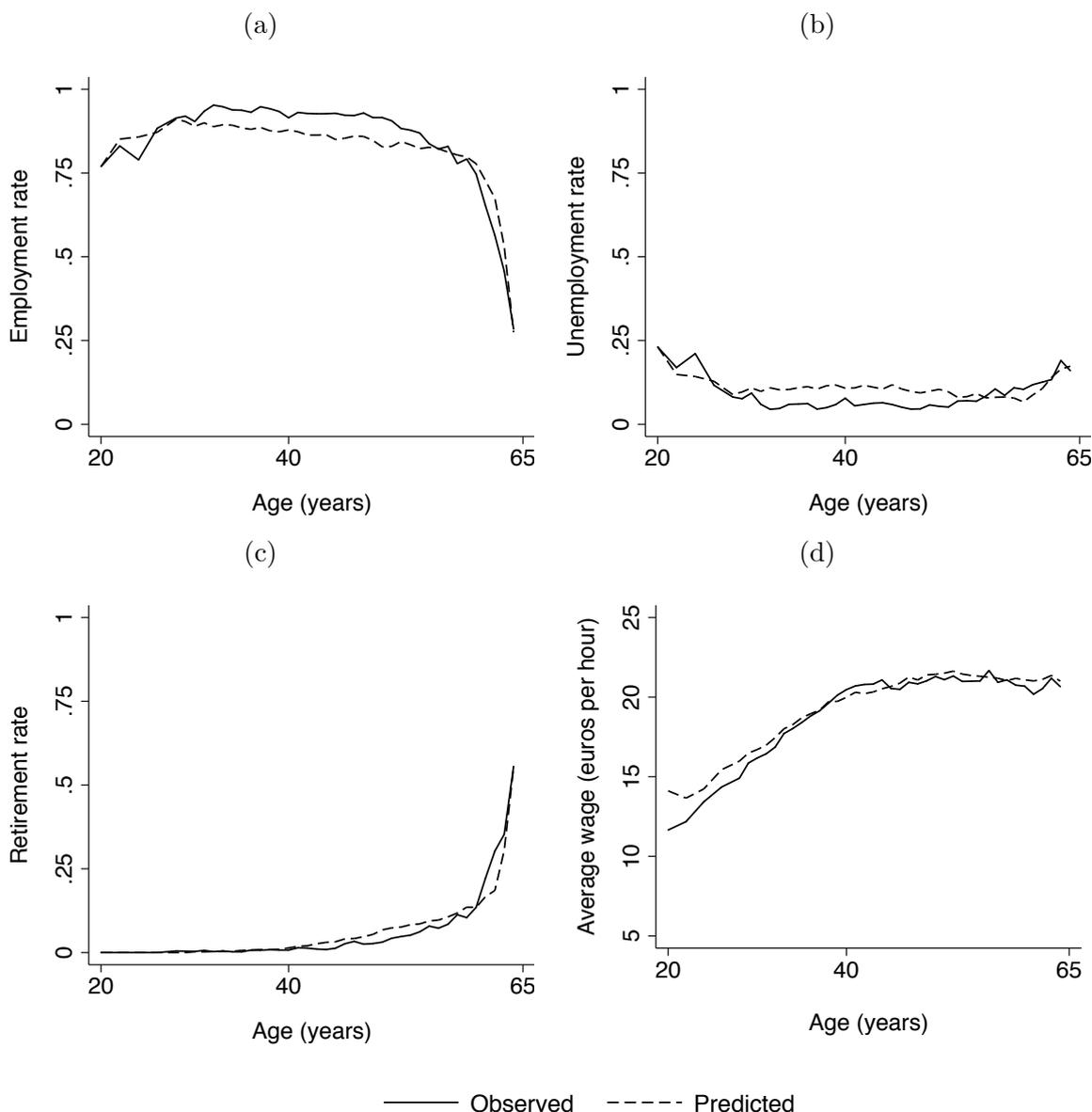
### Appendix IV.4: In-sample fit

Figures SWA.1(a)-(c) shows that the estimated model captures accurately the life-cycle profiles of employment and wages. Figure SWA.2 shows that the estimated model fits the distribution of wages, both overall and when we split the sample based on years of education. Figure SWA.1(d) shows that the model predicts a realistic retirement profile. This further supports the model specification.

Given that we use the estimated model to study the inequality of lifetime earnings and lifetime income, it is important that the estimated life-cycle model replicates accurately the persistence in labor supply and earnings that we see in the estimation sample. We explore the ability of the estimated model to fit the observed persistence in employment and unemployment by comparing the distributions of individual-level measures of persistence across the estimation sample and a sample simulated using the estimated model (the notes to Figure SWA.1 describe the simulated sample). We define employment persistence for an individual as the fraction of an individual's time in the sample during which he was employed (e.g., employment persistence is 33% for an individual who was in the sample for 6 years and was employed for 2 of these years). We use the same method to derive measures of persistence in unemployment. Table SWA.2 shows that the estimated model reproduces the patterns of persistence in employment and unemployment that we observe in the estimation sample. For example, 12% of individuals in the estimation sample are employed for 50% or fewer of the years that they were in the sample, compared to the model prediction of 13.5%. Similarly, among individuals in the estimation sample, 93.9% spent less than 50% of their time in unemployment, while the model predicts 93.2%.

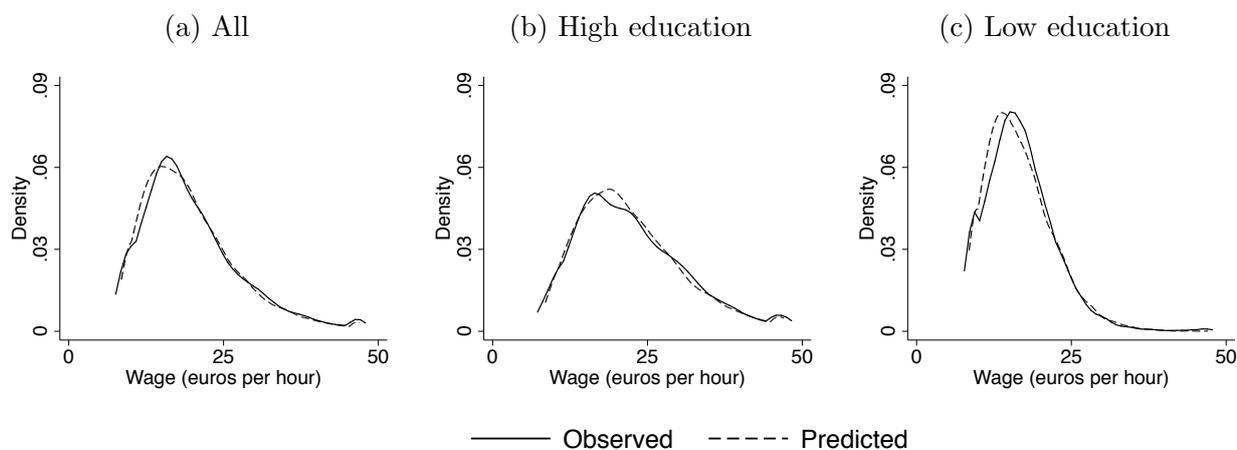
Similarly, we document the ability of the estimated model to fit the observed persistence in labor earnings. In particular, for each individual, we calculate the average of his annual labor earnings over the years during which he was in the sample and employed. We refer to this as the individual-level average of annual earnings. We then compare the distributions of the individual-level average of annual labor earnings across the estimation sample and a sample simulated using the estimated model (the notes to Figure SWA.1 describe the simulated

Figure SWA.1: Observed and predicted age profiles of labor supply and wages



*Notes:* Observed values were calculated using the estimation sample, which contains 3,281 individuals and 20,843 individual-year observations. Predicted values were calculated using a simulated sample. The simulated sample was constructed by using the estimated life-cycle model to simulate three life-cycle trajectories of labor supply and wages for each of the 3,281 individuals in the estimation sample. Each individual in the simulated sample was endowed with the level of education observed for the individual in the estimation sample and a productive ability drawn from the estimated distribution of productivity ability (see Panel III of Table 1). Simulated wage values include measurement error. To ensure comparability with the estimation sample, predicted values were calculated using only simulated outcomes from the age values at which the individual was observed in the estimation sample, and when calculating predicted wage values we further restrict the simulated sample by including only individuals who are employed in the simulation.

Figure SWA.2: Observed and predicted distributions of wages



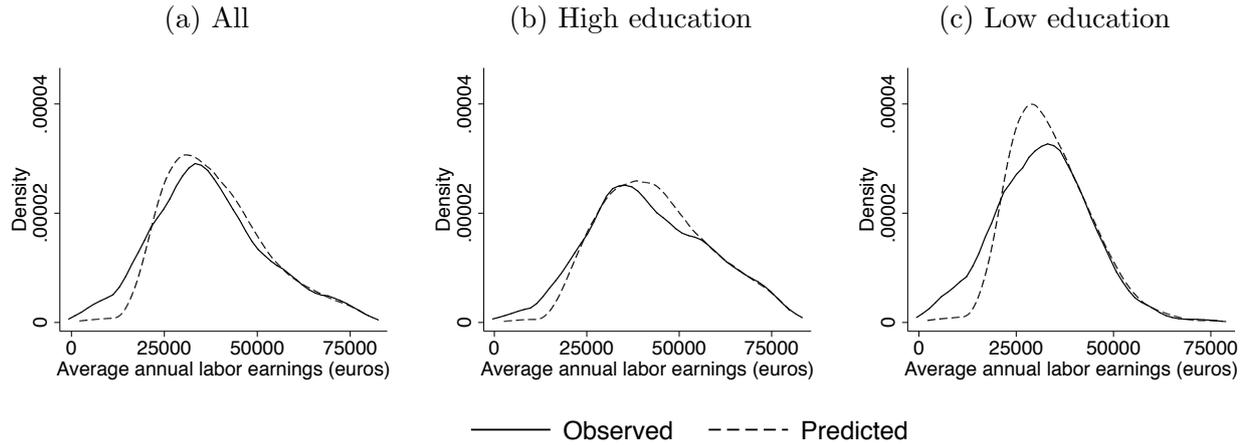
*Notes:* Observed values were calculated using the estimation sample. Predicted values were calculated using a simulated sample (the notes to Figure SWA.1 describe the simulated sample). To ensure comparability with the estimation sample, predicted values were calculated using only simulated outcomes from the age values at which the individual was observed in the estimation sample. For both samples, we focus on employed individuals aged 20-59 years inclusive.

Table SWA.2: Observed and predicted persistence in labor supply

Percentage of time	Percentage of individuals			
	In employment		In unemployment	
	Observed	Predicted	Observed	Predicted
= 0	7.5	6.8	81.0	76.1
≤ 25	8.5	8.5	88.6	85.9
≤ 50	12.0	13.5	93.9	93.2
≤ 75	16.7	21.0	95.4	96.4
≤ 100	100	100	100	100

*Notes:* Observed values were calculated using the estimation sample. Predicted values were calculated using a simulated sample (the notes to Figure SWA.1 describe the simulated sample). To ensure comparability with the estimation sample, predicted values were calculated using only simulated outcomes from the age values at which the individual was observed in the estimation sample. Persistence in a particular labor market state is measured at the individual level and is defined as the fraction of individual's time in the sample during which he was observed in the relevant labor supply state. For both samples, persistence measures were calculated using individuals aged 20-59 years inclusive.

Figure SWA.3: Observed and predicted persistence in labor earnings

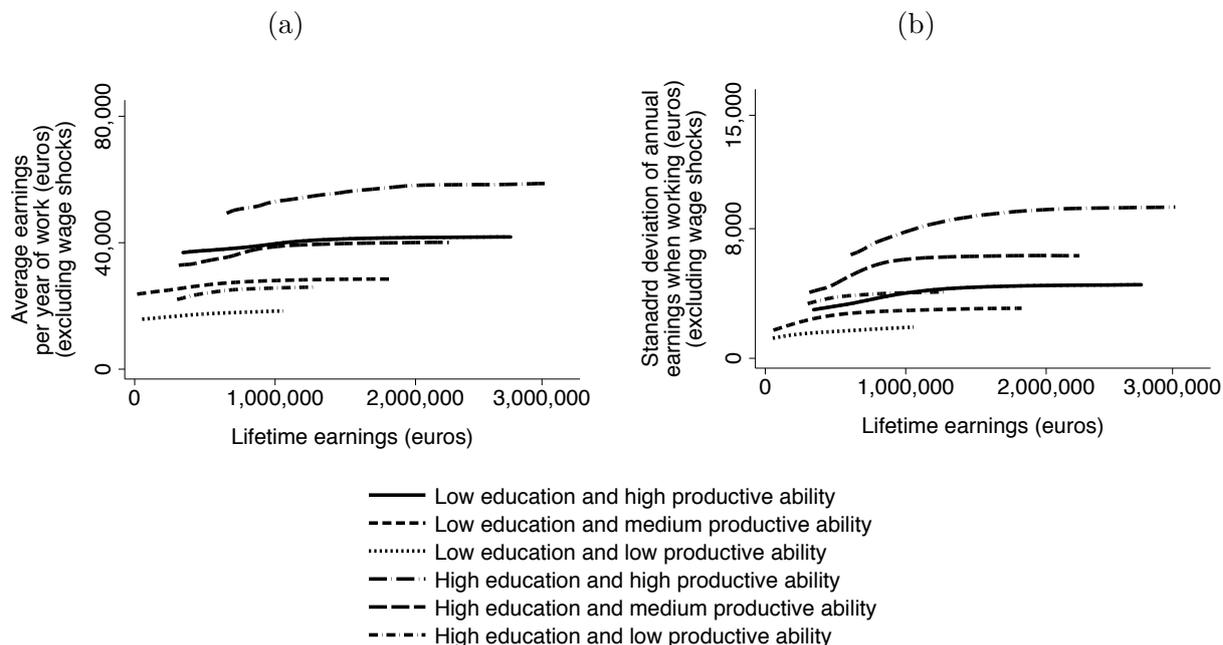


*Notes:* ‘Average annual labor earnings’ is the individual-level average of annual labor earnings over the years that the individual was in the sample. Individuals with zero average annual labor earnings (i.e., those individuals who never worked during the sample period) are excluded from all figures. Across all individuals, the observed and predicted fractions of individuals with zero average annual labor earnings are 7.5% and 6.8%, respectively. The corresponding figures are 5.7% and 5% for individuals with at least twelve years of education and 9.4% and 8.8% for individuals with fewer than twelve years of education. Also see the notes to Figure SWA.2.

sample). Note, the individual-level average of annual labor earnings combines information about employment persistence over the life cycle with information about wages, and it therefore provides a summary measure of individual-level labor earnings dynamics. Figure SWA.3 shows that the estimated model fits the distribution of individual-level average of annual labor earnings observed in the estimation sample. Also, when we split the samples based on whether an individual has less than twelve years of education or at least twelve years of education, the model continues to fit the distribution of average annual labor earnings within each educational category.

## Appendix V: Further results

Figure SWA.4: Insurance effects of taxation without wage shocks



*Notes:* Smoothed Nadaraya-Watson kernel regressions estimated using the simulated sample described in the notes to Table 4. ‘Low education’ refers eleven years of education and ‘high education’ refers to fourteen years of education.

## Appendix VI: Robustness checks

Table SWA.3: Robustness of the results in Table 4 to measuring inequality using the squared coefficient of variation instead of the Theil index

	Inequality of lifetime earnings and lifetime income (100 × squared coefficient of variation)			Ratio of between-endowment inequality to total inequality
	Total	Within-endowment	Between-endowment	
Earnings (Labor earnings+ interest income)	7.68	3.29	4.38	0.57
Income (Earnings–taxes+transfers)	4.02	1.60	2.42	0.60
Share of earnings inequality offset by the tax-and-transfer system	0.48	0.51	0.45	

Table SWA.4: Robustness of the results in Table 4 to measuring inequality using the mean logarithmic deviation instead of the Theil index

	Inequality of lifetime earnings and lifetime income (100 × mean logarithmic deviation)			Ratio of between-endowment inequality to total inequality
	Total	Within-endowment	Between-endowment	
Earnings (Labor earnings+ interest income)	8.75	4.22	4.53	0.52
Income (Earnings–taxes+transfers)	4.06	1.62	2.44	0.60
Share of earnings inequality offset by the tax-and-transfer system	0.54	0.62	0.46	

Table SWA.5: Robustness of the results in Table 5 to measuring inequality using the squared coefficient of variation instead of the Theil index

	Total	Within-endowment (Insurance)	Between-endowment (Redistribution)
Taxes	0.28	0.19	0.35
Unemployment insurance	0.03	0.03	0.02
Disability benefits	0.05	0.14	-0.01
Social assistance	0.12	0.15	0.10

Table SWA.6: Robustness of the results in Table 5 to measuring inequality using the mean logarithmic deviation instead of the Theil index

	Total	Within-endowment (Insurance)	Between-endowment (Redistribution)
Taxes	0.24	0.14	0.34
Unemployment insurance	0.03	0.04	0.02
Disability benefits	0.08	0.18	-0.01
Social assistance	0.19	0.27	0.11

Table SWA.7: Robustness of the results in Table 7 to measuring inequality using the squared coefficient of variation instead of the Theil index

	Within-endowment inequality in baseline	$\Delta$ Within-endowment inequality		
		Increased job separation risk	Decreased job offer rate	Increased risk of bad health shocks
Lifetime earnings (Labor earnings+ interest income)	3.29	0.17	0.53	0.36
Lifetime income (Earnings–taxes+transfers)	1.60	0.06	0.26	0.13
Share of extra within-endowment inequality offset by the tax-and-transfer system		0.63	0.51	0.62

Table SWA.8: Robustness of the results in Table 7 to measuring inequality using the mean logarithmic deviation instead of the Theil index

	Within-endowment inequality in baseline	$\Delta$ Within-endowment inequality		
		Increased job separation risk	Decreased job offer rate	Increased risk of bad health shocks
Lifetime earnings (Labor earnings+ interest income)	4.22	0.24	1.05	0.55
Lifetime income (Earnings–taxes+transfers)	1.62	0.06	0.32	0.15
Share of extra within-endowment inequality offset by the tax-and-transfer system		0.74	0.69	0.73

Table SWA.9: Robustness of the results in Table 8 to measuring inequality using the squared coefficient of variation instead of the Theil index

	Increased job separation risk	Decreased job offer rate	Increased risk of bad health shocks
Taxes	0.10	0.13	0.11
Unemployment insurance	0.06	-0.02	0.02
Disability benefits	0.22	0.11	0.36
Social assistance	0.25	0.29	0.13

Table SWA.10: Robustness of the results in Table 8 to measuring inequality using the mean logarithmic deviation instead of the Theil index

	Increased job separation risk	Decreased job offer rate	Increased risk of bad health shocks
Taxes	0.07	0.09	0.07
Unemployment insurance	0.05	0.01	0.03
Disability benefits	0.24	0.17	0.35
Social assistance	0.37	0.42	0.28