Wealth for health?

Martin Kerndler[1], Alexia Prskawetz[1,2], Miguel Sánchez-Romero[2]

[1] Institute of Statistics and Mathematical Methods in Economics, TU Wien
[2] Wittgenstein Centre for Demography and Global Human Capital (IIASA, OeAW, University of Vienna), Vienna Institute of Demography

February 28, 2022
PRELIMINARY DRAFT

Abstract

We study the impact of mortality risk at the workplace on mortality differentials. To this purpose we build a life-cycle search and matching model with wealth accumulation where on-the-job mortality risk is bargained between workers and firms. Our quantitative analysis shows that wealthy individuals optimally choose lower mortality risk. Getting wealthy, however, either requires higher risk-taking in the early career or a favorable labor market history.

1 Motivation

Mortality differentials by socioeconomic characteristics have widened over the last decades in several countries (Corsini 2010; Murtin et al. 2017; Murtin et al. 2021). These developments are of great concern since other existing inequalities (by education, wealth, income, etc.) may be exaggerated by differences in life expectancy. Recently it has also been argued that social security systems that aim to be progressive may even turn regressive if such mortality differences are ignored (Pestieau and Ponthiere 2016; Ayuso, Bravo, and Holzmann 2017; Holzmann et al. 2019; Sanchez-Romero, Lee, and Prskawetz 2020; Sanchez-Romero and Prskawetz 2020; Haan, Kemptner, and Lüthen 2020; Bravo et al. 2021).

A vast empirical literature exists offering various explanations how these differences in mortality come about (Christensen, Johnson, and Vaupel 2006; Fenelon and Preston 2012; Olshansky et al. 2012; Hummer and Hernandez 2013; Chetty et al. 2016; Caselli et al. 2017; Luy, Zannella, et al. 2019; Murtin et al. 2021). However, so far economic behavioural models that aim to endogenously explain these mortality differentials are rather limited (Capatina 2015; Galama and Van Kippersluis 2019; Fonseca et al. 2021). Commonly these models rely on exogenous heterogeneity across individuals by e.g. innate ability, initial wealth stock, etc. In this paper we offer an alternative mechanism that may generate part of these mortality differentials over life endogenously through the labor market. Empirical evidence (Luy, Wegner-Siegmundt, et al. 2015; Paglione et al. 2020) clearly indicates that the occupational status is correlated with

mortality. We propose a framework where individuals negotiate with firms over the mortality risk taken on the job. In equilibrium, higher mortality risk will be rewarded by a higher wage since firms can reduce their expenses on health protection. The worker's risk-taking behavior is affected by her financial wealth and the value of unemployment. Phases of involuntary unemployment increase the preference for high income and thus high risk-taking during employment spells. This implies a trade-off between accumulating wealth and preserving health. Once an individual has reached a sufficiently high level of wealth, however, her need for high income reduces, allowing lower risk-taking. In this case, health and wealth are complementing each other. Within our framework, we aim to quantify the extent of mortality differentials that can be explained by risk-taking on the job and investigate the mediating role of wealth.

2 The model

We implement a life-cycle search and matching model with asset accumulation and exogenous retirement along the lines of Lalé (2019). Joint with wages, firm and worker negotiate the level of on-the-job risk which determines the worker's conditional survival probability as in Kerndler (2021). In comparison to this paper, we put on-the-job risk into a life-cycle perspective to account for age differences in risk-taking, and allow individuals to self-insure against unemployment and mortality risk by accumulating savings.

2.1 Individuals

Individuals face two risks: the risk of dying and the risk of becoming unemployed. The risk of dying is compounded by an exogenous mortality risk factor, that depends on age, and a factor related to her labor market stage. Individuals can be in three labor market states: employment ($\mathcal{L}$), unemployment ($\mathcal{U}$), and retirement ($\mathcal{R}$). Let $\mathcal{X} = \{\mathcal{L}, \mathcal{U}, \mathcal{R}\}$ be the set of possible labor market stages and let x, x' be two elements of the set $\mathcal{X}$; $x, x' \in \mathcal{X}$. Individuals start their lives in unemployment ($x = \mathcal{U}$) and in each period have a probability of $p(\theta)$ of finding and taking up a job. Employed individuals face the risk of becoming unemployed with probability s. Thus, during working life, the employment state is governed by a two-state Markov chain with transition probabilities between employment and unemployment

$$\Gamma = \begin{pmatrix} \mathcal{L}\mathcal{L} & \mathcal{U}\mathcal{L} \\ \mathcal{L}\mathcal{U} & \mathcal{U}\mathcal{U} \end{pmatrix} = \begin{pmatrix} 1-s & p(\theta) \\ s & 1-p(\theta) \end{pmatrix}, \tag{1}$$

where s is the separation probability and $p(\theta)$ is the job-finding probability. During employment ($x = \mathcal{L}$), individuals supply their labor inelastically in exchange for a wage rate $w(\pi_t)$, which depends on their survival probability π_t resulting from work-related health hazards. In unemployment ($x = \mathcal{U}$), individuals receive an exogenous income of z. We abstract from modeling an unemployment insurance system and interpret this as home production. At an exogenous age T_R, individuals switch to retirement ($x = \mathcal{R}$). Consumption during retirement is financed by home production z as well as the previously accumulated wealth.

2.1.1 Value functions

Irrespective of the employment state, individuals face a consumption-savings decision. Employed individuals additionally decide on the level of on-the-job risk π_t. The expected utility that is maximized by an individual at age t (W_t) in state $x \in \mathcal{X}$ with assets a_t is

$$W_t(a_t, x) = U(c_t|x) - \mathbf{1}_{\{x=\mathcal{L}\}} d(1 - \chi \boldsymbol{\pi}_t(x)) + \beta \boldsymbol{\pi}_t(x) \, \mathbf{E}_t \left[W_{t+1}(a_{t+1}, x') | x \right], \tag{2}$$

where $U(c)$ is a standard period utility function (with $U(c) > 0$, $U'(c) > 0$, and $U''(c) < 0$) depending on consumption c. The term d is the disutility of work, which is assumed to linearly decrease at a rate $\chi > 0$ with the survival rate, $\boldsymbol{\pi}_t(x)$ is the conditional survival probability at age t in each stage, which is given by

$$\boldsymbol{\pi}_t(x) = \hat{\pi}_t \cdot \begin{cases} \pi_t & x = \mathcal{L}, \\ \pi_U & x = \mathcal{U}, \\ \pi_R & x = \mathcal{R}, \end{cases} \tag{3}$$

with $\hat{\pi}_t$ denoting the age-specific underlying survival rate, and π_t, π_U, π_R denoting the additional conditional survival rate based on the labor market status. While π_U and π_R are exogenous, the survival probability on the job π_t is endogenously chosen.

Consumption-savings decision. Individuals choose their consumption c to maximize (2) subject to the stage-dependent asset dynamics

$$a_{t+1}|x = \begin{cases} \frac{R}{\boldsymbol{\pi}_t(x)}(a_t + w(\pi_t) - c_t) & x = \mathcal{L}, \\ \frac{R}{\boldsymbol{\pi}_t(x)}(a_t + z - c_t) & x = \mathcal{U}, \mathcal{R}. \end{cases} \tag{4}$$

Employed individuals derive income from wages $w(\pi_t)$, while unemployed and retired individuals receive the value of home production z. The gross interest rate R in the economy is exogenous. We assume an annuity market which equally distributes the wealth of deceased individuals among the survivors of the respective group. Therefore the effective gross interest rate on savings is $R/\boldsymbol{\pi}_t(x)$. It is straightforward to obtain the first-order condition for consumption

$$U'(c_t|x) = R\beta \, \mathbf{E}_t \left[W'_{t+1}(a_{t+1}, x') | x \right],$$

as well as the envelope condition

$$W'_t(a_t, x) = R\beta \, \mathbf{E}_t \left[W'_{t+1}(a_{t+1}, x') | x \right].$$

Combining the two equations gives the consumption Euler equation

$$U'(c_t|x) = R\beta \, \mathbf{E}_t \left[U'(c_{t+1}|x') | x \right],$$

which together with the asset dynamics (4) determines optimal consumption.

Optimal level of on-the-job risk Employed individuals additionally decide on the optimal surivival probability on the job, π_t. Notice that the effective interest rate is beyond the influence of the individual. The fist-order condition (FOC) with respect to π_t can be written

$$d\chi\hat{\pi}_t + \beta\hat{\pi}_t \mathbf{E}_t \left[W_{t+1}(a_{t+1}, x')|\mathcal{L}\right] = -U'(c_t|\mathcal{L})w'(\pi_t). \tag{5}$$

The left-hand side of (5) reflects the marginal gain of increasing the survival probability. The first term is the immediate gain from a lower disutility of work, while the second term is the discounted stream of expected utility gained from living longer. The right-hand side of (5) reflects the marginal cost of increasing the survival probability. As will become clear below, firms are willing to reward higher on-the-job risk with higher wages. Therefore, marginally increasing the survival probability reduces a worker's wage, $w'(\pi_t) < 0$, and thereby utility.

To get further intuition of Eq. (5) it is convenient to define the value of life of a worker as $\text{VoL}_{t|\mathcal{L}} = \mathbf{E}_t \left[W_{t+1}(a_{t+1}, x')|\mathcal{L}\right]/U'(c_t|\mathcal{L})$. The value of life converts the lifetime utility, which is measured in "utils", into monetary equivalent units. Dividing both sides of (5) by $U'(c_t|\mathcal{L})$ and using the newly defined variable gives

$$-w'(\pi_t) = \frac{d\chi\hat{\pi}_t}{U'(c_t|\mathcal{L})} + \beta\hat{\pi}_t \text{VoL}_{t|\mathcal{L}}. \tag{6}$$

The optimal survival rate chosen by an individual satisfies that the marginal loss in income equals the monetized reduction in the disutility of work plus the monetary value gained from living longer.

2.2 Firms

Firms are risk neutral and each has one job which can be either filled or vacant, $x \in \{\mathcal{F}, \mathcal{V}\}$. Due to free entry of firms into the labor market, in equilibrium the value of a vacancy is $J(\mathcal{V}) = 0$. The value of a filled job depends on the characteristics of the employed worker. If the worker dies, the firm is left with a vacancy, such that

$$J_t(a_t, \mathcal{F}) = y_t(\pi_t) - w(\pi_t) + \beta\boldsymbol{\pi}_t(\mathcal{L})\, \mathbf{E}_t[J_{t+1}(a_{t+1}, x')|\mathcal{F}]. \tag{7}$$

The period firm profit is $y_t(\pi_t) - w(\pi_t)$. A match generates an effective output of $y_t(\pi_t)$, which captures total output minus the costs of safety measures. We do not explicitly model the costs of risk prevention since these could either require expenditures (like machine maintenance) or reduce a worker's productivity (due to wearing safety gloves etc.). The effective output function y_t is assumed to be strictly decreasing, $y_t' < 0$, and strictly concave, $y_t'' < 0$. This reflects that measures to reduce mortality risk (increase survival) on the job become increasingly costly at the margin, the higher the intended reduction in mortality (increase in survival).

2.3 Wage determination

At the beginning of a period, each worker negotiates with its employer a wage schedule $w(\pi_t)$. The wage schedule will depend on the worker's state (t, a_t), i.e. her age t and wealth a_t, since this determines the remaining value of the match.

We assume that firms understand how the level and slope of the wage schedule $w(\pi_t)$ affects the optimal π_t^* chosen by the worker, i.e. that $\pi_t^*(w, w')$ by (5). Since everybody anticipates the level of π_t that is chosen by the worker after the negotiation, the firms and the worker effectively only need to bargain about the wage level $w_t^* = w(\pi_t^*)$ and the wage gradient $w_t'^* = w'(\pi_t^*)$ that prevails at $\pi_t = \pi_t^*$. It is evident from (5), that by choosing these two variables, any desired level of π_t can be implemented as the worker's optimal decision. It is thus mathematically equivalent to bargain over w_t^* and π_t^*, and then set $w_t'^*$ by the worker's optimality condition (5). The bargaining outcome maximizes the generalized Nash product

$$(W_t(a_t, \mathcal{L}) - W_t(a_t, \mathcal{U}))^\gamma J_t(a_t, \mathcal{F})^{1-\gamma} \tag{8}$$

where $\gamma \in (0, 1)$ is the bargaining weight of the worker. The FOCs for w_t and π_t are

$$(1-\gamma)\frac{W_t(a_t, \mathcal{L}) - W_t(a_t, \mathcal{U})}{U'(c_t|\mathcal{L})} = \gamma J_t(a_t, \mathcal{F}), \tag{9}$$

$$(1-\gamma)\frac{W_t(a_t, \mathcal{L}) - W_t(a_t, \mathcal{U})}{\frac{\partial W_t(a_t, \mathcal{L})}{\partial \pi_t}} = -\gamma \frac{J_t(a_t, \mathcal{F})}{\frac{\partial J_t(a_t, \mathcal{F})}{\partial \pi_t}}, \tag{10}$$

where

$$\begin{aligned}
\tfrac{\partial W_t(a_t, \mathcal{L})}{\partial \pi_t} &= d\chi\hat{\pi}_t + \beta\hat{\pi}_t \, \mathbf{E}_t \left[W_{t+1}(a_{t+1}, x') | x \right], \\
\tfrac{\partial J_t(a_t, \mathcal{F})}{\partial \pi_t} &= y_t'(\pi_t) + \beta\hat{\pi}_t \, \mathbf{E}_t [J_{t+1}(a_{t+1}, x') | \mathcal{F}].
\end{aligned}$$

In arriving at these expressions, we assume that agents take future bargaining outcomes as given and beyond their influence in period t. Since w_t affects a_{t+1} and therefore w_{t+1}, the effect of today's bargaining outcome on future bargaining outcomes would otherwise need to be taken into account. We do not consider this realistic, however, and neglect these effects like Lalé (2019). Substituting (9) into (10) pins down π_t^* as solution to

$$-y_t'(\pi_t^*) = \frac{d\chi\hat{\pi}_t + \beta\hat{\pi}_t \, \mathbf{E}_t[W_{t+1}(a_{t+1}, x')|\mathcal{L}]}{U'(c_t|\mathcal{L})} + \beta\hat{\pi}_t \, \mathbf{E}_t[J_{t+1}(a_{t+1}, x')|\mathcal{F}]. \tag{11}$$

Given π_t^*, the associated wage level $w(\pi_t^*)$ is pinned down by (9). Given these values, the slope of the wage schedule that leads the worker to optimally choose π_t^* is easily computed from (6).

The bargaining solution has an interesting efficiency property. By (5), the first term in (11) equals $-w'(\pi_t^*)$, such that

$$y_t'(\pi_t^*) - w'(\pi_t^*) + \beta\hat{\pi}_t \, \mathbf{E}_t[J_{t+1}(a_{t+1}, x')|\mathcal{F}] = 0.$$

Note that this equals the first order condition that would result from (7) if the firm were to choose the worker's survival probability. Therefore, the negotiated wage schedule is such that at π_t^*, the firm's optimal supply of on-the-job risk coincides with the worker's optimal demand. Although the survival probability is the result of a negotiation where both parties have monopoly power, the outcome mimics properties of a competitive solution. Still, the level of π_t^* will be different in a competitive labor market. Since the wage level is determined by Nash bargaining, it depends on the bargaining weight γ, which further affects the level of consumption c_t and the continuation values on the right-hand side of (11).

2.4 Equilibrium

We now formulate the stationary equilibrium of our model.

2.4.1 Labor market

We assume that there is a single labor market in the economy where the mass of unemployed U search for jobs. These are brought together with vacancies V according to a constant returns to scale matching function $M(U,V)$. The probability that a vacancy meets a worker is $q(\theta) = \frac{M(U,V)}{V} = M(1/\theta, 1)$ where $\theta := V/U$ is the labor market tightness. Similarly, the probability that an unemployed meets a vacancy is $p(\theta) = \frac{M(U,V)}{U} = \theta q(\theta)$.

Taking this into account, the value of a vacant job for the firm is

$$\begin{aligned} J(\mathcal{V}) &= -c + \beta\, \mathbf{E}[J_t(a_t, x')|\mathcal{V}] \\ &= -c + \beta q(\theta) \int \max\{J_t(a_t, \mathcal{F}), J(\mathcal{V})\}\, dF_{\mathcal{U}}(t, a_t) + \beta(1 - q(\theta))J(\mathcal{V}). \end{aligned}$$

An open position generates a cost of c in the current period but attracts a worker with probability $q(\theta)$, who starts working in the next period. In line with most of the labor market literature, we assume that each firm receives only one application and accepts it if the value of the resulting filled job exceeds the value of a vacancy, $J_t(a_t, \mathcal{F}) \geq J(\mathcal{V})$. Since only unemployed are applying to jobs, the changes of hiring an individual with characteristics (t, a_t) equals the share of (t, a_t) individuals among the unemployed population, denoted by $dF_{\mathcal{U}}(t, a_t)$. Due to free entry of firms into the labor market, in equilibrium the value of a vacancy is $J(\mathcal{V}) = 0$, such that the equilibrium labor market tightness θ satisfies

$$\frac{c}{q(\theta)} = \beta \int \max\{J_t(a_t, \mathcal{F}), 0\}\, dF_{\mathcal{U}}(t, a_t).$$

2.4.2 Demography

The equilibrium mass of employed and unemployed of age t, respectively, evolve according to

$$\begin{pmatrix} L_{t+1} \\ U_{t+1} \end{pmatrix} = \begin{pmatrix} 1-s & p(\theta) \\ s & 1-p(\theta) \end{pmatrix} \begin{pmatrix} \overline{\boldsymbol{\pi}}_t(\mathcal{L}) & 0 \\ 0 & \boldsymbol{\pi}_t(\mathcal{U}) \end{pmatrix} \begin{pmatrix} L_t \\ U_t \end{pmatrix}$$

for $t = 0, \ldots, T_R - 1$, where the average conditional survival probability of employed individuals at age t is

$$\overline{\boldsymbol{\pi}}_t(\mathcal{L}) = \hat{\pi}_t \int \pi_t^* \, dF_{t|\mathcal{L}}(\pi_t^*),$$

where $dF_{t|\mathcal{L}}(\pi_t^*)$ is the share of age t individuals whose optimal on-the-job risk is π_t^*. Every individual starts out without a job, implying $L_0 = 0$, and $U_0 = N_0$, where N_0 is the mass of newborns. Since everybody retires at age T_R, the mass of retired workers satisfies

$$R_t = \begin{cases} 0 & t < T_R, \\ L_t + U_t & t = T_R, \\ \boldsymbol{\pi}_t(\mathcal{R}) R_{t-1} & t > T_R. \end{cases}$$

To ensure a stationary population, the mass of newborns equals the mass of deceased in each period,

$$N_0 = \sum_{t=0}^{T_R - 1} \left[(1 - \overline{\boldsymbol{\pi}}_t(\mathcal{L})) L_t + (1 - \boldsymbol{\pi}_t(\mathcal{U})) U_t \right] + \sum_{t=T_R}^{\infty} (1 - \boldsymbol{\pi}_t(\mathcal{R})) R_t.$$

3 Quantitative analysis

3.1 Parametrization

We use a CRRA utility function with intertemporal elasticity of substitution σ_C,

$$U(x) = \begin{cases} \dfrac{x^{1-1/\sigma_C} - 1}{1 - 1/\sigma_C} & \sigma > 0, \ \sigma \neq 1, \\ \ln(x) & \sigma = 1. \end{cases}$$

The effective output function is assumed to be isoelastic with an elasticity of output with respect to on-the-job risk of $\sigma_y \in (0, 1)$,

$$y_t(\pi_t) = \overline{y}(1 - \pi_t)^{\sigma_y}. \tag{12}$$

This function satisfies $y_t(1) = 0$ such that nothing can be produced without risk. On the other hand, effective output is bounded by $y_t(0) = \overline{y}$ where $\overline{y}$ is the production capacity of an individual.

In our benchmark parametrization, we use log-utility ($\sigma_C = 1$) and an output elasticity of $\sigma_y = 0.25$. The maximum output level $\overline{y}$ is equal to 60. We abstract from discounting $\beta = R = 1$ and set the labor supply parameters to $d = \chi = 1$. Drawing on Shimer (2005), the negotiation power is set to $\gamma = 0.725$ and we impose a home production z that is approximately 40% of the total income received by the individual. The separation rate is $s = 0.05$. The matching function is Cobb-Douglas, $M(U, V) = kU^{\gamma_M} V^{1-\gamma_M}$, and the Hosios (1990) condition is satisfied, $\gamma_M = \gamma$. The value of k is set at 1.0. The cost of posting a vacancy is set at 2.5 in order to get an unemployment rate close to 5% in the benchmark simulation.

The baseline age-specific survival $\hat{\pi}_t$ follows a Gompertz law (i.e. $\hat{\pi}_t = \exp\{-\alpha_\pi \exp\{\beta_\pi t\}\}$).

The parameters of the Gompertz law ($\alpha_\pi = e^{-10}$, $\beta_\pi = 0.075$) are chosen so as to have a maximum life expectancy close to 90 years. The conditional survival probability for the unemployed is $\pi_U = 0.993$, reflecting empirical studies that mortality is higher for unemployed than for employed (Gerdtham and Johannesson 2003; Eliason and Storrie 2009; Sullivan and Wachter 2009; Paglione et al. 2020). Individuals enter the model at age 20 ($t = 0$) and retire at age 65 ($T_R = 45$). The survival rate during retirement, π_R is uniformly distributed between π_U and 1. This assumption is introduced to minimize the positive (resp. negative) effect of retirement on survival that occurs when $\pi_R = 1$ (resp. $\pi_R = \pi_U$).

3.2 Results

In this section we quantitatively analyze the effect of wealth on health produced by the model. To this purpose, we generate simulations, using the model described in eqs. (1)-(11), in which each cohort is comprised of $N_0 = 1\,000$ randomly drawn agents that initially differ with respect to their additional conditional survival probability during retirement, with $\pi_R \sim U(\pi_U, 1)$. Agents can live a maximum of one hundred years though, during their life cycles, they will face unemployment risks (see Eq. 1) and mortality risks (see Eq. 3).

The descriptive statistics of four alternative simulations are shown in Table 1. The choice of the simulations allow us to test the effect of wealth on health under different labor market settings. We do so by comparing the benchmark case to three alternative simulations (in which we change only one exogenous variable) that respond to the following question: what is the impact of wealth on health in an economy with higher unemployment rate (Experiment I), higher output elasticity to on-the-job risk (Experiment II), and a longer working life (Experiment III)? A higher output elasticity to on-the-job risk implies that workers are less productive for the same level of on-the-job risk. Table 1 is divided in three panels. The top panel (a) reports the induced population characteristics: total population size (N), the distribution of the population across the three life stages (employment, unemployment, and retirement), and the overall unemployment rate. The middle panel (b) reports the mean and the standard deviation of eight endogenous variables (mortality rate, wage rate, firm output, consumption, wealth, firm value, the probability that an unemployed meets a vacancy, and the labor market tightness). Note that all the results in panel (b) are conditional on being employed. This is so because in this paper we are interested in the effect of work as a driver of inequality in mortality (i.e. $m_t = 1 - \hat{\pi}_t \pi_t$). The bottom panel (c) shows six exogenous variables: the elasticity of output to on-the-job risk, the separation rate, home production, the production capacity, the retirement age, and the additional conditional survival during retirement.

Through the descriptive statistics we can directly analyze the overall impact of different labor market settings on: the average life expectancy of the population, the wage rate per worker, output per worker, the average value of the firm, and the consumption per worker. Since we have assumed a stationary population (i.e. zero population growth), the life expectancy (at age 20) is obtained by dividing the total population size (N) by the initial size of a cohort (N_0). Comparing the alternative simulations to the benchmark, we obtain that the life expectancy

declines from 63.4 years to 62.7 years the higher is the separation rate and to 61.5 years the higher is the output elasticity to on-the-job risk, while the model suggests that the life expectancy increases from 63.4 years to 63.5 years the latter is the retirement age. The wage rate and the output per worker increase from 13.96 and 14.12 to 14.05 and 14.28, respectively, the higher is the unemployment rate, since individuals take a higher risk, and decline to 11.5 and 11.62, respectively, the higher is the output elasticity to on-the-job risk, since individuals are less productive for the same on-the-job risk level. Notice that a longer working life has no effect on the wage rate and output per worker. The consumption per worker, the financial wealth per worker, and the average value of the firm decline from 11.20, 39.18, and 1.61 to 10.96, 35.14, and 1.51, respectively, the higher is the unemployment rate –despite the positive influence of a higher unemployment rate on wages and output– and also decline to 9.03, 29.33, and 1.19 the higher is the output elasticity to on-the-job risk.

Table 1: Descriptive statistics of four alternative simulations

Variable		Benchmark		Experiment I[a]		Experiment II[b]		Experiment III[c]	
(a) Population characteristics									
Population	N	63 396		62 693		61 459		63 460	
Employed	L	38 553		35 316		36 553		38 591	
Unemployed	U	2 074		4 962		3 268		2 040	
Retired	R	22 768		22 416		21 639		22 829	
Unemployment rate	$\frac{U}{L+U}$	5.10%		12.32%		8.21%		5.02%	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
(b) Endogenous variables									
(conditional on being employed)									
Mortality rate†	m	500.61	(288.73)	502.47	(250.59)	605.77	(288.67)	486.89	(244.46)
Wage rate	w	13.96	(1.12)	14.05	(1.18)	11.50	(1.17)	13.96	(1.12)
Firm output	y	14.12	(1.09)	14.28	(1.11)	11.62	(1.14)	14.11	(1.09)
Consumption	c	11.20	(0.16)	10.96	(0.20)	9.03	(0.15)	11.19	(0.16)
Wealth	a	39.18	(34.59)	35.14	(32.66)	29.33	(29.12)	39.39	(34.70)
Firm value	J	1.61	(0.76)	1.51	(0.72)	1.19	(0.63)	1.61	(0.76)
Prob. unemployed meets a vacancy	$p(\theta)$	0.98		0.90		0.85		0.98	
Lab. market tightness	θ	0.92		0.69		0.57		0.93	
(c) Exogenous variables									
Output elasticity to on-the-job risk	σ_y	0.25		0.25		0.30		0.25	
Separation rate	s	5%		10%		5%		5%	
Home production	z	6.94		6.94		5.42		6.94	
Production capacity	$\bar{y}$	60.0		60.0		60.0		60.0	
Retirement age	$T_R + 20$	65.0		65.0		65.0		70.0	
Additional conditional survival during retirement†	π_R	99 645	(205.74)	99 660	(202.09)	99 660	(202.09)	99 660	(202.10)

Notes: †Values reported per 100 000 individuals. [a] Experiment I: higher separation rate; [b] Experiment II: higher output elasticity to on-the-job risk; [c] Experiment III: higher retirement age.

We complement the information provided in Table 1 by showing in Figure 1 the age profiles for three key variables: wage rate, mortality rate, and wealth. Panel (A) shows the age profiles of wage rates, panel (B) the age profiles of the mortality rate for all workers, panel (C) the

age profiles of wealth for all workers, and panel (D) contains a scatter plot of the association between the log mortality rate and the log wage rate from age 25 (t=5) to age 60 (t=40). It is interesting to see in panel (A) how the model generates an increasing wage rate with age except for the last year before retirement. As stated in (9), the positive slope of the wage rate by age is driven by the fact that, as agents get older and accumulate more wealth, the marginal benefits of increasing the wage rate increases faster than the marginal cost of paying the additional wage for firms. The increasing mortality rate with age, as panel (B) shows, is driven by an age-specific underlying mortality ($\hat{\pi}_t$), that is common to all workers, while the heterogeneity is caused by the different on-the-job risk taken by each worker. Panel (C) shows, consistently with the life cycle model, that workers accumulate wealth in order to finance the consumption after retirement. And panel (D) shows a clear positive association between the log mortality rate and the log wage rate at each age, which suggests that agents require a higher risk-taking in order to receive a higher wage rate. However, from Figure 1, we cannot disentangle several important effects. For instance, does wealth positively or negatively affect the risk-taking and hence the wage rate? Does the impact of wealth on mortality change across the working life? To answer these questions, we estimate in the next section the marginal effect using econometric techniques.

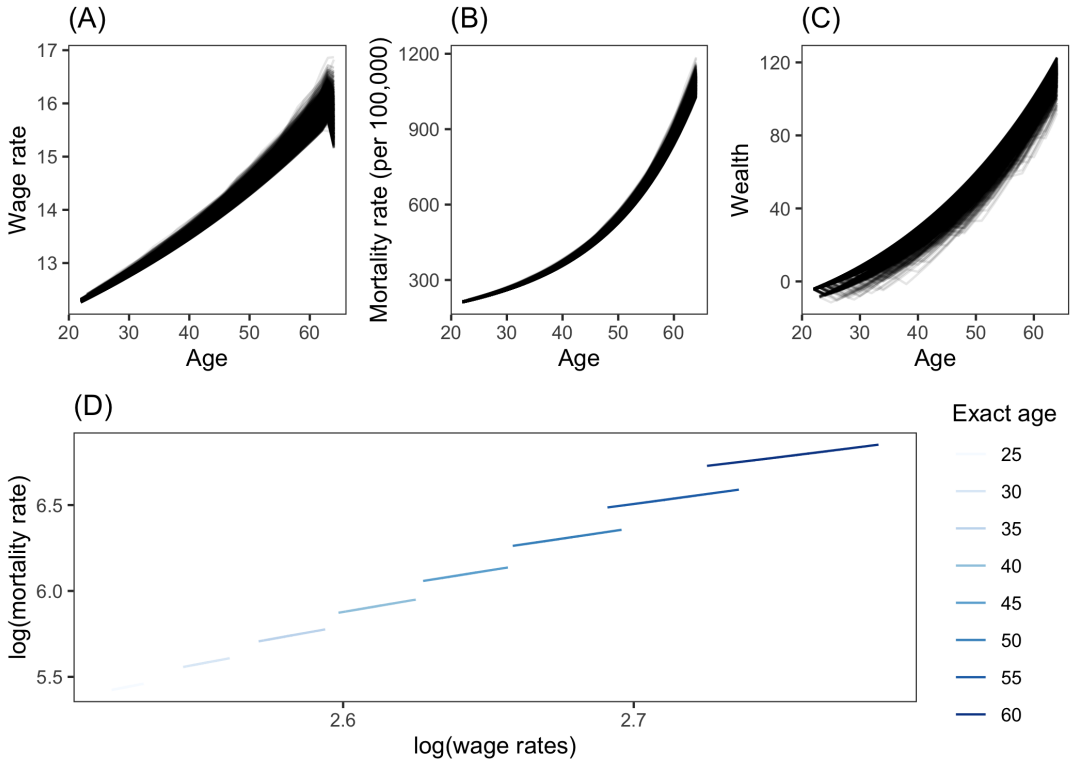


Figure 1: Simulated age profiles of wage rates (A), mortality rates (B), wealth (C), and the relationship between log wage rate and log mortality rate at each exact age (D). Case: Benchmark. Data source: Own simulations.

3.2.1 The effect of wealth on health and on the wage rate

Our empirical analysis begins by estimating the effect of wealth on mortality and of wealth on the wage rate. To do so we estimate the following two equations

$$\log(m_t) = \alpha_1 \log(a_t) + \alpha_2 \log(\pi_R) + \delta_t + \nu_t \log(a_t) + u_t, \tag{13}$$

$$\log(w_t) = \beta_1 \log(a_t) + \beta_2 \log(\pi_R) + \xi_t + \eta_t \log(a_t) + v_t, \tag{14}$$

where m_t denotes the mortality rate at age t (measured in terms of per one hundred thousand individuals), w_t is the wage rate, and a_t is the financial wealth. To control for the initial heterogeneity, we include the term π_R, which is the additional conditional survival probability during retirement. The terms δ_t, ν_t , ξ_t, and η_t denote age-fixed effects. The age-fixed effects capture the baseline mortality in (13) and the underlying age-profile of the wage rate in (14). u_t and v_t are the error terms.

To guarantee a positive wealth, we restrict the sample to agents older than 40. The OLS estimates for $\hat{\alpha}_1$ and $\hat{\beta}_1$ are reported in panel (a) in Table 2 for the benchmark case and for the three alternative labor market settings (experiments I-II). The estimated coefficients suggest, after controlling for the age of agents, that a one percent increase in wealth leads to a reduction in mortality of -0.036 percent and a reduction in wages of -0.01 percent.[1] Equivalently, an increase in the average wealth by one standard deviation leads to an average increase of $0.12(\approx 38.55 \cdot (34.59/39.18) \cdot 0.003465)$ years in employment, after controlling for age. This is because wealthier agents have a lower incentive to bargain over high wages, since they can better finance their consumption and increase their chances to reach retirement. Therefore, we can conclude that wealthy agents optimally choose lower mortality and wages. The positive effect of wealth on health (i.e. survival) is however dampened when either the unemployment rate or the output elasticity to on-the-job risk increases ($\hat{\alpha}_1 = -0.028$). In contrast, the positive effect of wealth on health marginally increases with longer working lives. We do not observe similar changes in the impact of wealth on wages under experiments I and II.

Is the impact of wealth on mortality rates and on wage rates constant across the working life? Using the interaction between the log of wealth and the age fixed-effects, Figure 2 graphically shows that the marginal impact of wealth on mortality (upper panels) and on wages (bottom panels) increases as agents get close to retirement. Therefore, the protection of wealth against having to accept risk-taking is higher for older agents than for agents early in their working lives. However, despite the increasing impact of wealth on mortality with age, it is important to bear in mind that the positive impact of wealth by age on the remaining years-worked should not be as pronounced, because the number of remaining years-worked also declines with age. It

[1] The average number of person-years lived in the labor market can be calculated as $e_W = ((1-m) - (1-m)^{n+1})/m$, where m is the average mortality rate of workers and n is the average number of years worked. Based on the formula e_W, the impact of a marginal increase in x on e_W is given by $\frac{x}{e_W}\frac{\Delta e_W}{\Delta x} = -\frac{x}{m}\frac{\Delta m}{\Delta x}\left[1 - \frac{m}{1-m}\left[n\frac{(1-m)^n}{1-(1-m)^n} - 1\right]\right]$. Thus, an increase of one percent in wealth leads to an increase in the person-years lived during work of $0.036\left(1 - \frac{0.005}{0.995}(38.55\frac{0.995^{38.55}}{1-0.995^{38.55}} - 1)\right) \approx 0.003465$ percent.

Table 2: Effect of wages on mortality and of mortality on wages

	Dependent variable:							
	Benchmark		Experiment I[a]		Experiment II[b]		Experiment III[c]	
	log(Mortality)	log(Wages)	log(Mortality)	log(Wages)	log(Mortality)	log(Wages)	log(Mortality)	log(Wages)
(a) First stage								
log(Wealth)	-0.036	-0.01	-0.028	-0.010	-0.028	-0.010	-0.038	-0.011
	(0.0003)	(0.0003)	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0003)	(0.0003)
$\log(\pi_R)$	-5.756	-2.505	-6.265	-2.771	-6.101	-2.823	-5.769	-2.515
	(0.007)	(0.006)	(0.014)	(0.009)	(0.015)	(0.009)	(0.007)	(0.006)
(b) Second stage (2SLS)								
log(Wages)	6.226	-	5.888	-	4.651	-	6.259	-
	(0.006)		(0.007)		(0.005)		(0.006)	
log(Mortality)	-	0.157	-	0.165	-	0.210	-	0.156
		(0.0002)		(0.0002)		(0.0002)		(0.0002)
Constant	-10.337	1.684	-9.447	1.633	-5.047	1.115	-10.423	1.688
	(0.017)	(0.001)	(0.018)	(0.001)	(0.011)	(0.001)	(0.017)	(0.001)
Controls								
Age-fixed effects	✓	✓	✓	✓	✓	✓	✓	✓
Observations	24 329		22 517		23 575		24 383	

Notes: †Values reported per 100 000 individuals. [a]Experiment I: Higher separation rate; [b]Experiment II: Higher output elasticity to on-the-job risk; [c]Experiment III: Higher retirement age.

is more interesting to observe the increasing willingness of wealthy agents to optimally choose lower wages as they get older. This result implies that when all agents have the same production capacity ($\bar{y}$), those who are wealthier, and hence have longer lives, negotiate lower wages than those who are poorer and have shorter lives.

Given that wealth prevents agents to take higher risk, how can agents accumulate more wealth and enjoy a longer life? There are two possibilities. The first possibility is merely luck in the labor market. When an agent finds a match with a firm early in life and does not get unemployed until retirement, the agent can save $w_t - c_t > 0$ units each year; otherwise the agent faces a cost of $c_t - z_t$ units each year. The second possibility is negotiating a higher wage rate at the expense of current health. In order to understand the trade-off between mortality and wages, next we investigate the extent to which an increase in the current wage rate leads to an increase in the current mortality rate.

Provided that on-the job risk (i.e. mortality rate) and the wage rate are simultaneously negotiated between each worker and the firm, causing that the endogenous regressors are correlated with the error term, the analysis is performed using two-stage least squares (2SLS), where we use as instruments the independent variables in (13) and (14). The set of equations solved are

$$\log(m_t) = \alpha_0 + \gamma \log(w_t) + e_t, \tag{15}$$

$$\log(w_t) = \beta_0 + \rho \log(m_t) + \varepsilon_t, \tag{16}$$

where e_t and ε_t are the error terms. The IV estimates of $(\alpha_0, \beta_0, \gamma, \rho)$ are reported in in Table 2, panel (b), for the benchmark case and the three alternative experiments. As expected, the IV estimators satisfy that $\gamma \approx 1/\rho$. The simulation results suggest that a one percent increase in the wage rate leads to an increase in the mortality rate of 6.226 percent in the benchmark case.

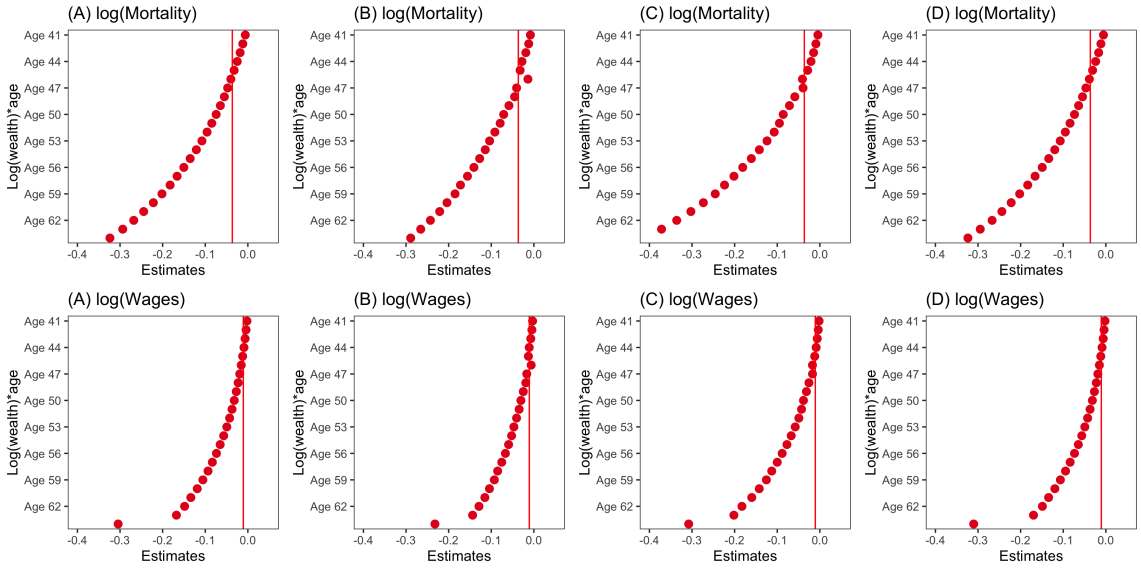


Figure 2: Marginal impact by age of wealth on mortality (upper panels) and wages (bottom panels). Cases: Benchmark (A), Experiment I. higher separation rate (B), Experiment II. higher output elasticity to on-the-job risk (C), Experiment III. higher retirement age (D). Notes: the vertical line corresponds to the impact of wealth on mortality and on wages regardless the age of the agent. Data source: Own simulations.

This is equivalent to a decrease in the average number of years worked of $0.6 (\approx 6.226 \cdot 0.0962565)$ percent or, when the wage rate increases by one standard deviation, the average number of years worked decline by $1.85 (\approx 38.55 \cdot (1.12/13.96) \cdot 6.226 \cdot 0.0962565)$ working years. See the derivation in footnote 2. Comparing the IV estimates in the benchmark to those in an economic setting with higher separation rate (Experiment I) suggests that workers have a higher negotiation capacity in Experiment I, that allows them to get a higher increase in their wage rates for taking a higher risk ($\hat{\rho}_{IV}$ is 0.165 in Experiment I and 0.210 in Experiment 2). This explains why the wage rate per worker (14.05) and the output (14.28) is higher in Experiment I than in the benchmark (13.96 and 14.12, respectively). Notice that we cannot make a similar comparison between Experiment II and the benchmark, since a higher output elasticity to on-the-job risk implies by definition a lower productivity per worker, and hence lower wages.

3.2.2 The effect of wealth on health with increasing heterogeneity

Thus far we have assumed agents only differ a priori in terms of their conditional survival probability after retirement. In this section, we extend the analysis by including the possibility that agents can also differ a priori according to either their retirement age or their production capacity. The analysis follows the same strategy as in the previous subsection. However, we change (13) and (14) in order to accommodate the new degree of heterogeneity. The first-stage

regressions in the case that retirement is heterogeneous are

$$\log(m_t) = \beta_1 \log(a_t) + \beta_2 \log(\pi_R) + \beta_3 T_R + \delta_t + \nu_t \log(a_t) + u_t,$$
$$\log(w_t) = \alpha_1 \log(a_t) + \alpha_2 \log(\pi_R) + \alpha_3 T_R + \xi_t + \eta_t \log(a_t) + v_t,$$

where T_R is the retirement age, with $T_R \sim U(40, 50)$. Hence, the average retirement age in the new simulation coincides with that in the benchmark. The IV approach for estimating the coefficients in (15) and (16) remains the same.

Comparing the descriptive statistics of the benchmark to the new simulation (not reported in the paper) shows that in an economy with heterogeneity in the retirement age the unemployment rate is lower (4.43 percent) and the life expectancy (at age 20) is slightly higher (63.48 years). In contrast, the mean values of all other variables remain almost the same as in the benchmark. Table 3 shows, in the upper panel (a), middle column, that when agents have different retirement ages, the positive marginal impact of wealth on health is halved relative to the benchmark, while the negative marginal impact of wealth on wages increases from -0.01 to -0.038. Moreover, we get that by delaying the retirement age by one additional year the mortality rate is reduced by 0.6 percent and the wage rate by 1.6 percent. This is explained because an additional year of work increases lifetime income, consumption, and hence the value of life, which makes agents to be less willing to take risks. The effect of wages on mortality and of mortality on wages do not differ significantly when comparing the new simulation to the benchmark.

Is there any differential impact of wealth on health across agents with different initial income levels? To answer this question we introduce heterogeneity with respect to the production capacity. Recall the production capacity can be thought of as a proxy for education or cognitive abilities that makes workers more productive. To include this additional heterogeneity we first assume that the production capacity of each agent ($\bar{y}$) is randomly drawn from the uniform distribution $U(40, 80)$. The additional heterogeneity with respect to the productivity capacity leads to an increase in unemployment from 5.1 (benchmark) to 7.39 percent, an increase in wealth and wages per worker and output from 39.18, 13.96, and 14.12 (benchmark) to 56.76, 14.44, and 14.59, respectively, a decline in the average life expectancy (at age 20) from 63.4 (benchmark) to 62.58, and a decline in consumption per worker and firm value from 11.2 and 1.61 (benchmark) to 10.51 and 1.5, respectively.

To understand the drivers of the increasing inequality (besides the inequality already introduced by the additional degree of heterogeneity), we modify the first-stage regressions (13)-(14) by including, firstly, the direct influence of productivity on mortality and of productivity on wages and, secondly, the interaction between assets and productivity. The coefficient on this interaction shows us whether the dampening effect of assets on mortality and wages is higher or lower for more productive workers. Thus, we have

$$\log(m_t) = \beta_1 \log(a_t) + \beta_2 \log(\pi_R) + \beta_4 \log(\bar{y}) + \beta_5 \log(\bar{y}) \log(a_t) + \delta_t + \nu_t \log(a_t) + u_t,$$
$$\log(w_t) = \alpha_1 \log(a_t) + \alpha_2 \log(\pi_R) + \alpha_4 \log(\bar{y}) + \alpha_5 \log(\bar{y}) \log(a_t) + \xi_t + \eta_t \log(a_t) + v_t.$$

Table 3: Effect of wages on mortality and of mortality on wages under increasing heterogeneity

	Dependent variable:					
	Benchmark		Heterogeneity in retirement		Heterogeneity in maximum production capacity	
	log(Mortality)	log(Wages)	log(Mortality)	log(Wages)	log(Mortality)	log(Wages)
(a) First stage						
log(Wealth)	-0.036	-0.01	-0.015	-0.038	-0.187	-0.086
	(0.0003)	(0.0003)	(0.001)	(0.001)	(0.005)	(0.002)
$\log(\pi_R)$	-5.756	-2.505	-2.978	-6.627	-4.438	-1.895
	(0.007)	(0.006)	(0.021)	(0.025)	(0.046)	(0.023)
Retirement, T_R	-	-	-0.006	-0.016	-	-
			(0.00003)	(0.00004)		
$\log(\bar{y})$	-	-	-	-	0.022	0.996
					(0.005)	(0.003)
$\log(\bar{y})$log(Wealth)	-	-	-	-	0.022	0.013
					(0.001)	(0.001)
(b) Second stage (2SLS)						
log(Wages)	6.226	-	6.324	-	6.063	-
	(0.006)		(0.008)		(0.006)	
log(Mortality)	-	0.157	-	0.153	-	0.162
		(0.0002)		(0.0002)		(0.0002)
$\log(\bar{y})$	-	-	-	-	-5.911	0.975
					(0.006)	(0.0003)
Constant	-10.337	1.684	-10.591	1.705	14.183	-2.321
	(0.017)	(0.001)	(0.022)	(0.001)	(0.010)	(0.002)
Controls						
Age-fixed effects	✓	✓	✓	✓	✓	✓
Observations	24 329		24,471		23 773	

Notes: Results restricted to ages above 40. First stage regressions estimated using OLS. All the estimated coefficients are significant at a level of $p < 0.01$.

In addition, since (11) and (12) imply that wages and survival are mediated by the production capacity of each worker, we include the direct influence of the production capacity into (15) and (16) as follows:

$$\log(m_t) = \beta_0 + \gamma_0 \log(w_t) + \gamma_1 \log(\bar{y}) + e_t, \tag{17}$$

$$\log(w_t) = \alpha_0 + \rho_0 \log(m_t) + \rho_1 \log(\bar{y}) + \varepsilon_t. \tag{18}$$

The column on the right-hand side, panel (a), in Table 3 reports the effects of wealth on mortality rates and wages. Notice from the new set of equations above that the overall effect of wealth, independently of the age of the agent, is given by

$$\frac{a.}{x.}\frac{\partial x.}{\partial a.} = \beta_1 + \beta_5 \log(\bar{y}) \text{ for } x. \in \{m., w.\}.$$

The positive sign of the interaction term between wealth and the underlying productivity of the worker implies that the dampening effect of assets on wages and mortality is lower for more productive workers. In particular, we have that a one percent increase in wealth leads to a reduction in wages of 0.038 percent for low productive workers ($\bar{y} = 40$) and of 0.029 for high

productive workers ($\bar{y} = 80$). Also, a one percent increase in wealth leads to a reduction in mortality of 0.106 percent for low productive workers and of 0.091 percent for high productive workers or, equivalently, an increase in wealth of one percent raises the average number of years worked by 0.39 years for low productive workers and by 0.34 years for high productive workers.

Notice that the estimated coefficients for the trade-off between wages and mortality, which are shown in the second-stage regressions in Table 3 (panel b), are similar to those obtained in the benchmark simulation. Hence, we conclude that wealth becomes more relevant for explaining differences in life expectancy when there is heterogeneity with respect to retirement age and the productivity capacity of workers.

4 Conclusion

Based on the fact that occupational status is correlated to mortality we offer a behavioural model that endogenously generates mortality differentials over life through the labour market. We implement a life-cycle search and matching model where firms and workers negotiate wages together with the level of on-the-job risk, which in turn determines the conditional survival probability of workers. Wages increase with on-the-job risk. Over the life-cycle higher unemployment rates increase the individuals risk taking behaviour, while higher wealth works in the opposite direction and reduces the risk taking of individuals.

Within our proposed framework we are able to test how health (as determined by on the job risk behaviour and measured by the resulting life expectancy) is determined by different labor market settings. We show that a higher separation rate at the labour market or a lower productivity of workers implies a lower life expectancy together with lower consumption and wealth. An increase in the retirement age on the contrary generates a slight increase in life expectancy, consumption and wealth. Our simulations clearly show an increasing heterogeneity of mortality with increasing age caused by the variation of the risk behaviour of workers. Hence, our framework offers a new model to understand mortality inequality across the workers life-cycle.

To understand the role of wealth accumulation for health (i.e. job risk behavior) we have run several regressions on our data generated through the simulations to disentangle the relation between wealth, mortality and wages. From our results we can conclude that wealthy agents optimally choose lower mortality and wages. Moreover, the positive effect of wealth on health is higher for older workers than for younger ones. Therefore, our analysis clearly shows a trade-off between wealth and mortality at the workplace. On the one side, agents require high risk-taking to become wealthy. On the other side, wealthier agents have a lower incentive to bargain over high wages in order to increase their chances to reach retirement. Hence, the model can be used for explaining the observed increasing inequality in mortality trend across workers.

When further heterogeneity with respect to either retirement age or production capacity is introduced in the model, we find that wealth becomes more relevant in explaining differences in life expectancy. However, we observe that the effect of wealth on risk-taking behaviour is lower for agents with high productivity capacity.

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