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Early retirement decisions: Lessons from a dynamic structural modelling

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Early retirement decisions: Lessons from a dynamic structural modelling.

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Abstract

Early retirement has many causes according to economic and sociological literature. These causes may be the preference for leisure, financial and health conditions, and social environment. In our paper, we aim to specify and estimate an econometric model to assess the early retirement decision-making process for aged workers. We specify a worker's utility function from which we derive worker's probability to retire earlier that depends on her health stock, estate value and preference for future. We also estimate an health production and an health consumption functions that are key factors in the individual's decision to retire earlier. Thus, we show that our model disentangles between three groups of workers: (i) those who choose early retirement, (ii) those who will never choose early retirement and (iii) those who are uncertain about early retirement. We also show that our predicted early retirement probability is a good predictor of early retirement as it is causal for observed early retirement.

Keywords: Early retirement, Grossmann Model, Space-state model, Causality

JEL Classification: C32, C51, I12, J26

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Introduction

There is a large literature in sociology and economics about the early retirement decision. These studies highlight the preference for leisure, the good financial conditions, the individual health conditions, the social environment, and the working environment as main factors of early retirement decision.

The individual preferences for leisure is related to the financial condition. For an individual, if early retirement does not deteriorate her financial condition then she is more likely to retire earlier; and this likelihood is greater when she prefers leisure (Brothers, 2000). In individual social environment, the retirement status of spouse specially and that of family members and neighbours in general can increase the likelihood of an individual to retire earlier (Brothers, 2000). Individuals with many post-retirement opportunities are more likely to retire earlier. These post-retirement opportunities can be related to the education level, the unemployment rate in the region, or the industry sector of worker. Individual health condition is one of the major factor that determines the labour force participation. The likelihood to continue working cannot be satisfy for an individual in very bad health condition. Thus, the perceived ability to remain in job market and the good working condition reduce the probability that individual early retires.

However, the use of relevant micro economics datasets to analyze the theoretical findings is recent. With the collection of recent specific datasets like the survey of health, ageing and retirement in Europe (SHARE), some applied micro economics papers have addressed the early retirement issue. These papers commonly use as dependent variable the binary variable that captures if or not the individual looks for early retirement. The dependent variable can also be constructed as a binary variable that is one if retirement age is under 65. One of the determinant that are commonly underlined in the literature is related to working conditions. Even if Quinn (1977) finds that there is no evidence of the influence of job characteristics and financial variables on early retirement for white married men in the US, many recent studies challenge this finding. Bazzoli (1985) finds that economic variables play more important role than health in retirement decision-making process. With the first wave of the SHARE dataset, Debrand and Blanchet (2008) show that being satisfy with job reduces the probability to look for early retirement. Mein et al (2000) also show on a British dataset that less satisfied workers are more likely to retire earlier. Early retirement is also specific to activity sector (Dorn and Sousa-Poza 2004). Alhawarin (2014) shows that workers in army and security forces sector in Jordan are more likely to retire earlier. Pollak (2012), by the use of a panel dataset from SHARE, shows that health status, job satisfaction and working condition are the major factors that explain the fact that individual looks for early retirement or not. She also highlights the important role of rewards in keeping in labour force older workers even with disabilities. Siegrist et al (2006) also show that effort reward imbalance and poor quality of work are main factors that explain that workers look for early retirement. The workload is also an important determinant of early retirement (Boumans et al, 2008). There are also empirical evidences that early retirement is related to earnings. Workers with higher-paid employment are more likely to retire earlier (Mein et al, 2000). Dorn and Sousa-Poza (2004), on the Swiss Labour force survey dataset, show that wage rate has a non linear effect on early retirement. Both workers with high and low wage are more likely to keep working. Dorn and Sousa-Poza also highlight the important role played by the coverage in the social security system. Quinn (1977) finds that eligibility to social security lower the probability to participate to labour market. Another main factor of early retirement to be highlighted is the post retirement opportunities for early retired. These opportunities are related with unemployment rate, school grade and activity sector (Brothers 2000) or to demographics characteristics such as living in couple and spouse employment status (Jiménez-Martin et al, 2015). Workers that retire earlier continue working after retirement (30% of them, see Dorn and Sousa-Poza 2004), even in jobs with a degree of informality (Alhawarin, 2014).

Health is also an important determinant for early retirement decision. Both current and perceived future health conditions play an important role in the decision of early retirement. Workers retire if they have poor health (Galama et al, 2013) or if they think that their future health condition will not allow them to continue working. Bazzoli (1985) suggests the use of current health status in addition of perceived future health limitations to better assess effect of health on early retirement. By analyzing a set of married white men aged between 58 and 63 extracted from the US social security administration's retirement history study, Quinn (1977) finds that health limitations lower the probability to participate to labour market. Coe and Zamarro (2008) use the SHARE dataset to show that retirement has a health-preserving effect on general health. They find that being retired reduces the probability to report bad health condition. Health problems increase the probability of early retirement (Albuquerque, 2009). Disability, severity of health shock, increased rate of sickness absence and alcohol abuse are strong determinants for early retirement (Szubert and Sobala 2005, Jiménez-Martin et al, 2006). Health shocks can also induce working hours reduction (Cai et al, 2006). The fear that health condition limits working abilities increases the probability to look for early retirement (Debrand and Blanchet, 2008). Boumans et al (2008) focus on Belgian older nurses and show that perceived health condition is a major determinant of early retirement.

Social environment of workers plays an important role in the decision of early retirement. The household wealth has a negative impact on early retirement (Alhawarin 2014). The family size (Albuquerque 2009 and Alhawarin 2014) is also a determinant of early retirement. However, the effect of the family size can be different among countries. Alhawarin (2014) finds that the family size increases the probability of early retirement in Jordan while Albuquerque (2009) shows that small family size increases the probability of early retirement. Another social environment variable that is determinant for early retirement is the partner employment status. This is important because couples coordinate their retirement decision (Albuquerque 2009). Many studies underlined the important role of partner employment status in early retirement decision (Dorn and Sousa-Poza 2004, Szubert and Sobala 2005, Boumans et al 2008, Albuquerque 2009, Jiménez-Martin et al, 2015). Workers with retired partner are more likely to retire earlier.

Finally, from the economic and sociological theory, it appears clearly that individual will retire earlier if (i) his health condition limits his capability to continue working, (ii) his perceived future health condition does not allow him to continue working, or (iii) he has a job with low quality.

In this paper, our main goal is to assess the early retirement decision process for aged workers. For this purpose, we take advantage of the Grossman model (1972) to specify and estimate a micro-economic model that accounts for workers financial, health, and working conditions and some socio-economics variables.

In Section 1, we present our microeconomic approach which, based on the Grossman model, provides us (i) a health production and (ii) a health consumption functions. In Section 2, we present the Survey on Health, Ageing and Retirement in Europe (SHARE) dataset and some related descriptive statistics. Based on the microeconomic specification of Section 1, we estimate the different equations of our model in Section 3. This allows us to get a predicted individual retirement probability at each time period. Conclusion gives some implications of our findings.

1 The economic model

In this section, we present the theoretical framework of the current paper. We first describe the dynamic of health stock equation and the dynamic of estate equation and we end by specifying the model and its constraints. Let $\rho_{i,t}$ denotes the retirement status of individual i at t, with $\rho_{i,t} = 1$ if individual i is retired at t and zero otherwise. Let $p_{i,t}$ denotes the retirement probability.

1.1 Health and estate equations

Based on Grossman's (1972) theory on health capital, we propose a health stock dynamic equation for workers. The original model proposed by Grossman (1972) is the following:

$$H_{i,t} - H_{i,t-1} = I_{i,t-1} - \delta_{i,t-1} H_{i,t-1} \tag{1}$$

where $\delta_{i,t-1}$ denotes the health depreciation rate at time $t-1$ for individual i, $H_{i,t}$ is the health stock at t and $I_{i,t-1}$, the investment in health at $t-1$ for individual i. In our context, as we focus on workers, it is possible to decompose health depreciation rate into three sources that are: (i) depreciation due to working condition, (ii) depreciation due to ageing since individuals become more vulnerable to illnesses with age, and (iii) natural depreciation due to impact of illnesses on health. Thus, from the original health stock dynamic equation, $\delta_{i,t}$ can be desegregated as follows:

$$\delta_{i,t} = \alpha_1 (1 - \rho_{i,t}) C_{i,t} + \alpha_2 Agesq_{i,t} + \alpha_3 Age_{i,t} + \alpha_4 H_{i,t} \tag{2}$$

Where $C_{i,t}$, $Age_{i,t}$, $Agesq_{i,t}$ and $H_{i,t}$ are respectively the working condition, age, the square of age and the health stock of individual i at the date t. To adjust his health stock to a desired level, worker can invest in his health stock. However, the decision to invest in health does not only depend on the need to adjust the health stock. It also depends on individual financial situation. An invest in health $I_{i,t}$ is produced by a function of the amount spent in health (Hall and Jones, 2007). Let f denotes the health production function by investment in health care or prevention, and $h_{i,t}$ the amount that the individual i spends for his health at t. Then, we can rewrite $I_{i,t}$ as $I_{i,t} = f(h_{i,t})$. Thus, the health stock at $t+1$ is given by:

$$H_{i,t+1} - H_{i,t} = f(h_{i,t}) - \Big(\alpha_1(1-\rho_{i,t})C_{i,t} + \alpha_2 Agesq_{i,t} + \alpha_3 Age_{i,t} + \alpha_4 H_{i,t}\Big)H_{i,t} \tag{3}$$

Dynamic in Equation 3 is useful: (i) to estimate how productive health expenditures are, and (ii) to disentangle the health depreciation due to job from the depreciation due to others factors.

Individual estate/worth includes financial assets, real assets and debts. The individual estate accumulation dynamic is the following:

$$E_{i,t} = (1+\pi)E_{i,t-1} + (1-\omega_i\rho_{i,t})W_{i,t} - h_{i,t} - c_{i,t} \tag{4}$$

where $E_{i,t}$, $W_{i,t}$, $c_{i,t}$, π, and ω_i are respectively estate, revenue from current job, total expenditures, the interest rate, and the share of last job income lost at retirement for individual i at period t.

1.2 Model, constraints and optimal state

There are two main factors at the period t on which individual can make a decision to maximize her utility. These controls are:

- Decision to retire: if an individual decides to work, her health stock decreases by $\alpha_1 C_{i,t} H_{i,t}$ due to health condition and her estate value increase of $\omega_i W_{i,t}$. The same analysis holds if individual retires. Let g denotes the health depreciation function due to job, we can express the health depreciation saved by a retirement as $\alpha_1 C_{i,t} H_{i,t} = g\big((1-\rho_{i,t})\omega_i W_{i,t}\big)$. Instead of a retirement/work scheme, we assume that workers can decide to reduce their working time from the full time work to a partial time work in order to preserve health decrease.

- Amount invested in health: investment in health stock that aims to slow down health depreciation rate by paying for care. It involves reducing estate level to earn a compensation of health stock depreciation. A unit increase in health expenditures $h_{i,t-1}$ increases the health stock by $f^{'}(h_{i,t-1})$.

We suppose that worker has a utility function that only depends on her consumption and health stock: $u(c_{i,t}, H_{i,t})$. We assume the following separable utility function form:

$$u(c_{i,t}, H_{i,t}) = \frac{c_{i,t}^{1-\lambda}}{1-\lambda} + a\frac{H_{i,t}^{1-\gamma}}{1-\gamma} \tag{5}$$

Where a, γ, and λ are positive parameters. Let r_i denotes the utility discount factor. We introduce a Bellman value function $V(E_{i,t+1}, H_{i,t+1})$ that depends on the estate and the health stock at $t+1$. Thus, the overall lifetime utility function is given by:

$$u_i = u(c_{i,t}, H_{i,t}) + r_i V(E_{i,t+1}, H_{i,t+1}) \tag{6}$$

An individual optimal state at t is a value of $h_{i,t}$ and $c_{i,t}$ that maximizes her utility. Thus, the worker's program is the following:

$$u_i = \underset{(c_{i,t},h_{i,t})}{Max}\left\{u(c_{i,t}, H_{i,t}) + r_i V(E_{i,t+1}, H_{i,t+1})\right\} \tag{7}$$

Subject to

$$H_{i,t+\tau+1} = f(h_{i,t+\tau}) + (1-\delta_{i,t+\tau}) * H_{i,t+\tau} \quad \forall\tau = 1, ..., T_c-1$$
$$E_{i,t+\tau+1} = (1+\pi)E_{i,t+\tau} + (1-\omega_i\rho_{i,t+\tau+1})W_{i,t+\tau+1} - h_{i,t+\tau+1} - c_{i,t+\tau+1} \quad \forall\tau = 1, ..., T_c-1$$

The first and second constraints are respectively health and estate accumulation constraints. The first order conditions of the maximization problem in Equation 7 above are given by:

$$\begin{aligned}\frac{\partial u_i}{\partial c_{i,t}} &= c_{i,t}^{-\lambda} - r_i(1+\pi)\frac{\partial V(E_{i,t+1}, H_{i,t+1})}{\partial E_{i,t+1}} = 0 \\ \frac{\partial u_i}{\partial h_{i,t}} &= -r_i(1+\pi)\frac{\partial V(E_{i,t+1}, H_{i,t+1})}{\partial E_{i,t+1}} + r_i f'(h_{i,t})\frac{\partial V(E_{i,t+1}, H_{i,t+1})}{\partial H_{i,t+1}} = 0\end{aligned} \tag{8}$$

where $f'(h_{i,t}) = \partial f(h_{i,t})/\partial h_{i,t}$. Then, using the envelop condition, the following optimal states are derived:

$$\begin{aligned}\left(c_{i,t+1}^*\right)^{-\lambda} &= \frac{1}{r_i(1+\pi)}\left(c_{i,t}^*\right)^{-\lambda} \\ \frac{1+\pi}{f'(h_{i,t}^*)} - \frac{1-\delta_{t+1}}{f'(h_{i,t+1}^*)} &= \frac{aH_{i,t+1}^{-\gamma}}{\left(c_{i,t+1}^*\right)^{-\lambda}}\end{aligned} \tag{9}$$

where $c_{i,t}^*$ and $h_{i,t}^*$ are function of $E_{i,t}$, $H_{i,t}$ and $\rho_{i,t}$. Then, the overall lifetime utility value at optimal state for individual i at t is given by:

$$u_{i,t}^* = u(c_{i,t}^*, H_{i,t}) + r_i V\big((1+\pi)E_{i,t} + (1-\omega_i\rho_{i,t+1})W_{i,t+1} - h_{i,t+1}^* - c_{i,t+1}^*, f(h_{i,t}^*) + (1-\delta_{i,t}) * H_{i,t}\big) \tag{10}$$

Thus, worker will choose $\rho^*_{i,t}$ that maximizes $u^*_{i,t}$; i.e. $\rho^*_{i,t} = \arg\left(\max_{\rho_{i,t}} \; u^*_i\left(E_{i,t}, H_{i,t}, \rho_{i,t}\right)\right)$. The early retirement probability is then given by $\hat{p}_{i,t} = P(\rho^*_{i,t} = 1)$.

Let now allow $\rho_{i,t}$ to be a continuous variable that ranges 0 to 1, with 1 meaning that worker choose retirement, 0 meaning worker continue full time work, and other values denote partial time work. We also assume that working a percent of full time job grant the equivalent percent of full time revenue. Then, the revenue from job is $(1-\rho_{i,t})\omega_i W_{i,t}$. Since the retirement decision taken for $t+1$ only affect the overall utility function at this date, the worker will choose $\rho_{i,t+1}$ that maximizes $u^*_{i,t+1}$. The optimal condition gives $\rho^*_{i,t+1}$ that fulfil:

$$\frac{g^{'}\left((1-\rho^*_{i,t+1})\omega_i W_{i,t+1}\right)}{1+\pi} = f^{'}\left(h^*_{i,t+1}\right) \tag{11}$$

Then, we deduce from Equation 11 that: (i) worker never chooses early retirement ($\rho^*_{i,t+1} = 0$) if the marginal productivity of her optimal health expenditure at $t+1$ equates her marginal health depreciation due to the salary share lost at retirement $\omega_i W_{i,t+1}$; (ii) worker always chooses early retirement ($\rho^*_{i,t+1} = 1$) if the marginal productivity of her optimal health expenditure at $t+1$ is infinite; and (iii) worker has uncertainty ($0<\rho^*_{i,t+1}<1$) if the marginal productivity of her optimal health expenditure at $t+1$ is finite but upper than marginal health depreciation due to the salary share lost at retirement.

2 Data and descriptive statistics

In this section, we give a short description of the Survey on Health, Ageing and Retirement in Europe (SHARE). Then, we briefly present our health and working conditions indicators construction methods before characterizing workers with respect to their health condition, their job characteristics and their social and financial situation.

2.1 Data from SHARE

The data set we use in this paper is an appended dataset of the waves of the SHARE data set. SHARE[1] is a longitudinal survey conducted each two years in European countries. It provides

[1]The SHARE data collection has been primarily funded by the European Commission through the 5th Framework Programme (project QLK6-CT-2001-00360 in the thematic programme Quality of Life), through the 6th

information on aged health condition, economic and social situation. It also includes the individual hopes[2] in terms of retirement. Some other important variables on health conditions, health care consumption, job characteristics, working environment, social variables, and financial condition (real and financial assets, and debts) are available.

As we are only interested on workers, we exclude from the dataset, all individuals that are non-workers as they first appear in the panel. We also exclude all individuals with only one observation period, as we are interested on the dynamic. After these cleaning up, we extract a subset of dataset that contains 17,568 individuals who are observed from 2 to 4 times (2.75 periods on average). Thus, the pooled dataset contains 44,331 observations.

2.2 Health stock and working condition indicators estimation

Both health and working condition are described by a set of categorical variables in SHARE dataset. To construct an index based on these categorical variables, we need an aggregation scheme. The main problem that has to be challenged is that of the weighting set we use to aggregate the dimensions.

The index construction based on the categorical variables can be down by the use of the multiple correspondence analysis (MCA) method[3]. But in our case, we use the ordinary probit model. We choose this approach because we have a self-reported global health condition and a self-reported global work satisfaction that are respectively variables of 5 and 4 levels scales. The approach we use consist in estimating an ordered probit model on the overall dataset (see Cutler and Richardson (1997) for further details on this approach). Let h^* and y^* denote respectively a latent variable that measures health and working condition, X_1 and X_2 denote two

Framework Programme (projects SHARE-I3, RII-CT-2006-062193, COMPARE, CIT5- CT-2005-028857, and SHARELIFE,CIT4-CT-2006-028812) and through the 7th Framework Programme (SHARE-PREP, N° 211909, SHARE-LEAP, N° 227822 and SHARE M4, N° 261982). Additional funding from the U.S. National Institute on Aging (U01 AG09740-13S2, P01 AG005842, P01 AG08291, P30 AG12815, R21 AG025169, Y1-AG-4553-01, IAG BSR06-11 and OGHA 04-064) and the German Ministry of Education and Research as well as from various national sources is gratefully acknowledged (see www.share-project.org for a full list of funding institutions)

[2]The question asked is: *... look for early retirement in main job ?*

[3]See Volle (1997) and Bry (1999) for further details on factorial analysis framework.

sets of demographic variables, D denotes observed diseases[4], M denotes mental health condition variables[5], and C denotes the working condition variables[6]. The estimated models are:

$$(1.2.1)\begin{cases} h^{*}=\beta_d D+\beta_m M+\beta_1 X_1+\epsilon^1 \\ h=j \;\; if \;\; c^1_{j-1}\leq h^{*}<c^1_j \;\; for \;\; j=1,...,5 \;\; with \; c^1_0=-\infty \, and \, c^1_5=+\infty \end{cases}$$

$$(1.2.2)\begin{cases} y^{*}=\beta_c C+\beta_2 X_2+\epsilon^2 \\ y=j \;\; if \;\; c^2_{j-1}\leq y^{*}<c^2_j \;\; for \;\; j=1,...,4 \;\; with \; c^2_0=-\infty \, and \, c^2_4=+\infty \end{cases}$$

The results of the estimated ordered probit models are in appendix 3 in Table 12 for health condition and Table 13 for working condition. For each of these two continue variables that values range from -9.5 to -0.28 for health stock and from -2.2 to 2.33 for working condition, we add a scalar to allow them to be positive. The scalar corresponds to the absolute value of the score for an individual who is in the worst condition. Thus, the health stock ranges from 2.7 to 11.92 while working condition index ranges from 0.64 to 5.17. Note that higher values of health stock denote healthier individual and higher values of working condition indicator denote that worker is in better working conditions.

2.3 Analysis of health stock and job satisfaction

This section aims to give a description of the health stock. We highlight the differences between workers and retired in health stock by testing for equality between these two groups (t-test). We also analyze the health stock differences between workers looking for early retirement and those who do not. Health stock is 9.3 in average in the pooled dataset[7]. However, it declines slowly from 9.6 at the first wave to 9.16 at the last wave. Health stock is also significantly lower

[4]Answers to the question *Doctor told you had:*, and the items are: heart attack, hypertension, cholesterol, stroke, diabetes, lung disease, asthma, arthritis, osteoporosis, cancer, ulcer, Parkinson disease, cataract, hip or femoral fracture.

[5]Self-reported variables: being sad or depressed, hopes for future, felt would rather be dead, trouble sleeping, less interest in things, irritability, lost of appetite, fatigue, concentration on reading and entertainment, enjoyment, tearfulness.

[6]Variables related to: job physically demanding, time pressure due to heavy workload, little freedom to decide how work is down, opportunity to develop skills, receiving support in difficult situation, receiving recognition for work, adequate earnings or salary, poor security, and poor prospects for job advancement.

[7]see Table 14 in appendix 4 for full statistics on health stock among waves and on overall dataset

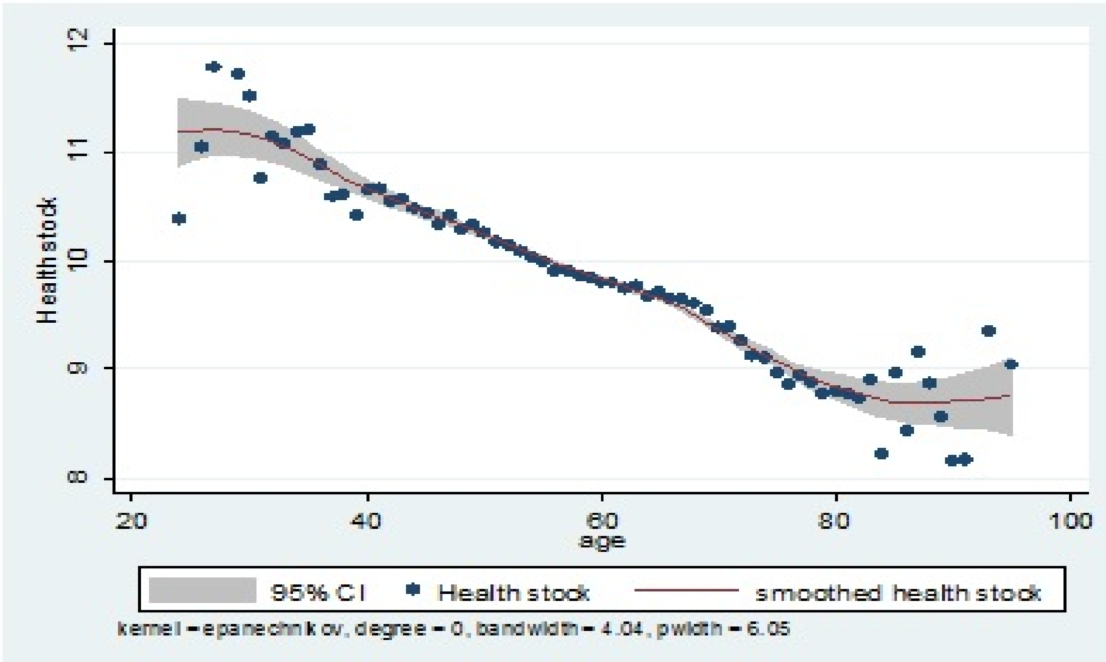

Figure 1: Evolution of health stock among age

for retired than workers. We also find a significant difference in health stock between workers looking for early retirement than those who do not. Furthermore, as we can see from Figure 1 the estimated health stock fulfills the common finding that is health stock declines with age.

Figure 3 in appendix 5 shows the dynamic of job satisfaction among age. It appears that elders are most satisfied than younger workers. Job satisfaction indicator registers a 33% growth from 50 to 75 years old.

2.4 Some determinants of early retirement in Europe

This section aims to compare workers that look for early retirement with those who do not. The comparison is based on some key socio economic variables that might have influence on the early retirement according to the literature. We perform a mean t-test (or proportion z-test) to confirm the equality between the two groups. As we can see from the Table 1, workers that are looking for early retirement are more likely to retire at the following period (differences around 5% in general).

The proportion of workers looking for early retirement slightly declines among time (from 43.3% to 39.9%). As we can see from Table 15 in appendix 4, workers looking for early retire-

Table 1: Retirement among European aged workers

Retired	Early+	Wave 2	Wave 4	Wave 5	Overall
Proportion of	Yes	0.1722 (0.0074)	0.348 (0.0098)	0.1959 (0.0059)	0.2268 (0.0043)
workers that	No	0.1342 (0.0058)	0.2676 (0.0078)	0.1579 (0.0043)	0.1774 (0.0033)
retire	Difference	0.038*** (0.0092)	0.0804*** (0.0125)	0.038*** (0.0072)	0.0494*** (0.0053)

+: worker looked for early retirement at last wave.

***: significant at 1% level. Standard errors are in parenthesis.

ment are significantly younger (1.2 year lower) than those who do not. Another relevant item is the fact who workers that are afraid that their health limits their ability to work are also significantly more likely to look for early retirement. It also clearly appears that workers looking for early retirement are less satisfied of their job and are in worst working condition. However, contrarily to the common understanding, workers with high school level are less likely to look for early retirement.

Workers looking for early retirement are not in better financial condition than those who do not (see Table 16 in appendix 4 for further details). Their annual earnings from job and the amount in their bank account are in average significantly lower. These evidences mean that workers with low earnings and savings prefer preserving their health instead of continuing working. Another important variable is the percentage of salary that worker will receive as pension if he retires. We find that workers looking for early retirement are those with higher (39.25% vs 32.83%) percentage of salary to be received as pension. When we turn to out-of-pocket health expenditures, we highlight from the pooled dataset that there is a significant difference (26.45€)between workers who do not look for early retirement and those who do.

Post retirement opportunities are determinant for retirement (Brothers, 2000; Dorn and Sousa-Poza, 2004; Alhawarin, 2014). Proportion of retired who continue working among elders workers still growing (from 3.2% to 10.1%). Estonia (28.4%), Israel (21.3%), France (12.8%), and Switzerland (8.8%)[8] are the countries that are most concerned are. Female workers are

[8]See Tables 17 and 18 in appendix 5 for further statistics on post retirement employment.

significantly less concerned than male in most of European countries. The share of retired workers in older workers population is significantly higher among workers with higher school level. This difference is gender specific for high skilled workers.

3 Empirical models and results

The proposed model has numerous parameters that have to be estimated. The main parameters we will discuss are the share of health depreciation due to working condition, the health consumption function and the health production function. Before estimating these two functions, we must estimate $I_{i,t}$ and $\delta_{i,t}$ from the Grossman model.

3.1 Empirical estimation of Grossman's model

Based on the Grossman model given by equation 1, many works have proposed reformulations for the empirical estimation of the reduced forms of the demand for health and demand for health care equations. Wagstaff (2002) underlines consistency problems with these empirical works. These empirical estimations lead to wrong signs of estimated coefficients due to inappropriate assumptions when moving from theoretical to empirical model[9]. To overcome this problem, Wagstaff (2002) assumes the desired health stock to be $H_t^* = \beta X_t + u_t$ where X_t is a set of exogenous variables. Wagstaff also assumes that individuals are not able to adjust instantaneously the health stock. Then he includes a fraction μ (between 0 and 1) that denotes the instantaneous adjustment rate of the desired health stock.

In our case, we construct an individual health stock indicator at each time period. Thus, only health investment I_t is unobserved. As δ is assumed to be individual and time variant, the equation to estimate is the following one:

$$H_{i,t} = I_{i,t-1} + (1 - \delta_{i,t-1})H_{i,t-1} + \xi_{i,t} \tag{12}$$

Where $\xi_{i,t} = \xi_i^1 + \xi_{i,t}^2$ with the individual effects $\xi_i^1 \sim \mathrm{N}(0,\sigma_1^2)$, the idiosyncratic error $\xi_{i,t}^2 \sim \mathrm{N}(0,\sigma_2^2)$ and ξ_i^1 supposed to be independent of $\xi_{i,t}^2$. This is a dynamic model with hidden

[9]See Wagstaff (2002) for further discussions on consistency problems with empirical reformulation of Grossman's model

factors $I_{i,t-1}$ and $\delta_{i,t-1}$. Thus, we use the space-state models framework that is helpful for that purpose (Peyrache and Rambaldi, 2012). From the specification in equation 12 above, two hidden states equations have to be defined: for the health investment $I_{i,t-1}$ and the health depreciation rate $\delta_{i,t-1}$. To achieve this goal, we make two assumptions. The first one is related to health investment. Individual health investment is assumed to have the following specification:

$$I_{i,t} = a_{1,0} + a_{1,1}I_{i,t-1} + a_{1,2}\delta_{i,t-1} + \xi^I_{i,t} \tag{13}$$

$$\delta_{i,t} = a_{2,0} + a_{2,1}I_{i,t-1} + a_{2,2}\delta_{i,t-1} + \xi^\delta_{i,t} \tag{14}$$

Where $\xi^I_{i,t} \sim N(0,\sigma^2_I)$ and $\xi^{\delta_1}_i \sim N(0,\sigma^2_\delta)$. By putting together the measurement equation in 12 and the two states equations 13 and 14, the overall state-space model to be estimated has the following form:

$$(3.1)\begin{cases} H_{i,t} = I_{i,t-1} + (1-\delta_{i,t-1})H_{i,t-1} + \xi_{i,t}\,, \forall t \geqslant 1 \\ I_{i,t-1} = a_{1,0} + a_{1,1}I_{i,t-2} + a_{1,2}\delta_{i,t-2} + \xi^I_{i,t-1}\,, \forall t \geqslant 2 \\ \delta_{i,t-1} = a_{2,0} + a_{2,1}I_{i,t-2} + a_{2,2}\delta_{i,t-2} + \xi^\delta_{i,t-1}\,, \forall t \geqslant 2 \end{cases}$$

The matrix state-space representation for the system 3.1 above is the following one:

$$\begin{aligned} H_{i,t} &= H_{i,t-1} + B_{i,t-1}\Gamma_{i,t-1} + \xi_{i,t}\,, \forall t \geqslant 1 \qquad (15) \\ \Gamma_{i,t-1} &= A_0 + A_1\Gamma_{i,t-2} + \Xi_{i,t-1}\,, \forall t \geqslant 2 \end{aligned}$$

With $A_0 = \begin{pmatrix} a_{1,0} \\ a_{2,0} \end{pmatrix}$, $A_1 = \begin{pmatrix} a_{1,1} & a_{1,2} \\ a_{2,1} & a_{2,2} \end{pmatrix}$, $\Gamma_{i,t-1} = \begin{pmatrix} I_{i,t-1} \\ \delta_{i,t-1} \end{pmatrix}$, $\Xi_{i,t-1} = \begin{pmatrix} \xi^I_{i,t-1} \\ \xi^\delta_{i,t-1} \end{pmatrix}$, and the transpose of B, $B'_{i,t-1} = \begin{pmatrix} 1 \\ -H_{i,t-1} \end{pmatrix}$.

Ξ and ξ are supposed to be uncorrelated (i.e the model is causal and invertible), and the covariance matrix structure for the errors vector Ξ in state equation is defined by:

$$\Sigma_\Xi = \begin{pmatrix} \sigma^2_I & \rho_{I,\delta}\sigma_I\sigma_\delta \\ \rho_{I,\delta}\sigma_I\sigma_\delta & \sigma^2_\delta \end{pmatrix}$$

To estimate the state-space model in Equation 15, we use a Kalman Filter algorithm[10] to provide value of state variables (I and δ). For initialization of the Kalman filter, we use:

$$\begin{aligned} \hat{\Gamma}_{i,1/1} &= E(\Gamma_{i,1}/H_{i,1}) = m_\Gamma \\ \Sigma_{i,1/1} &= V(\Gamma_{i,1}/H_{i,1}) = P_\Gamma \end{aligned}$$

[10]Further details on the Kalman filter derivation are given in appendix 2

With $m_\Gamma = E(\Gamma_{i,1})$ and $P_\Gamma = V(\Gamma_{i,1})$, that are parameters for initial states. Droesbeke et al (2013) argue that m_Γ can be any real value vector and $P_\Gamma = \lambda I$ with the scalar λ very large and I the identity matrix. This approach that consists to set a large λ can be inappropriate (De Jong 1988, 1991a, 1991b). Thus, De Jong (1991a) proposes a diffuse Kalman filter or to model the state space model as diffuse (De Jong, 1991b) and some algorithms to solve the model. These specifications allow to estimate the model without setting P_Γ. Even if we suppose the model not to be diffuse, the approach by De Jong improves the Kalman filter by including a recursion.

The individual level log-likelihood function can be rewritten as follows (further details in appendix 1):

$$LL_i = \frac{1}{2}\left(-log(1+\sigma_1^2 \sum_{t=1}^{T} M^{-1}_{i,t/t-1}) - \sum_{t=1}^{T} \left[M^{-1}_{i,t/t-1} h^2_{i,t} + log(2\,\pi M_{i,t/t-1}) \right] + \frac{\sigma_1^2 \left(\sum_{t=1}^{T} M^{-1}_{i,t/t-1}\, h_{i,t} \right)^2}{(1+\sigma_1^2 \sum_{t=1}^{T} M^{-1}_{i,t/t-1})} \right) \tag{16}$$

Where $h_{i,t} = H_{i,t} - \hat{H}_{i,t/t-1} + \xi_i^1 = H_{i,t} - B_{i,t-1}\hat{\Gamma}_{i,t-1/t-1}$, , and $det(M_{i,t/t-1}) = M_{i,t/t-1}$ since $M_{i,t/t-1}$ is a scalar. For likelihood calculation, we use $\hat{H}_{i,t/t-1}$ and $M_{i,t/t-1}$ provided by the Kalman filter. The parameters of the model described in equation 15 that have to be estimated are σ_1, σ_2, A_0, A_1, and Σ_Ξ. The maximization algorithm has two major steps that are iterated until convergence:

- for a fixed value of model's parameters, use the Kalman filter to estimate $\hat{H}_{i,t/t-1}$ and $M_{i,t/t-1}$, then compute the log-likelihood LL_i
- improve the model parameters to maximize the log-likelihood LL_i

Estimations results are in Table 2. We find a significant bidirectional causal link between investment and depreciation. The higher health stock depreciation is, the lower the health investment will be. This finding denotes that the older are less likely to demand for health care when their health stock depreciation rate is high. Conversely, the higher the health investment is, the higher the health stock depreciation rate will be. An increase in demand for health care for older augurs an increase in health depreciation rate.

Table 2: Estimated coefficients of the state space model

Variable	Measurement ($H_{i,t}$) Equation 12	Investment ($I_{i,t}$) Equation 13	Depreciation ($\delta_{i,t}$) Equation 13
$I_{i,t-1}$	–	-0.8293^{***} (0.0352)	1.2696^{***} (0.1412)
$\delta_{i,t-1}$	–	-0.0448^{**} (0.0212)	0.0688 (0.0730)
Intercept	–	-0.00004 (0.0579)	-0.00004 (0.0567)
Variance covariance structure			
σ_1	0.000069	–	–
σ_2	0.00096	–	–
σ_I	–	5.4931^{***} (0.1303)	–
σ_δ	–	–	5.1494^{***} (0.1281)
$\rho_{I,\delta}$	–	0.8999^{***} (0.1082)	

***: significant at 1% level, **: significant at 5% level, Standard errors are in parenthesis.

3.2 Health production and health consumption function

In this section, we estimate an health consumption and health production functions. These functions are key functions in the retirement process.

As described in section 2, individual can invest in health and this investment can be interpreted as input for an health production function. Let assume the health production function to be $\hat{I}_{i,t} = f(h_{i,t}) = A_{0,i}Exph_{i,t}^{\varphi}$ where $\hat{I}_{i,t}$ denotes the produced health by an invested health expenditures $h_{i,t}$, and $A_{0,i}$ denotes individual and country specifics variables that are determinant of health investment. We also include $J-1$ country dummies that are supposed to capture technological differences between countries. Thus the log-linear form we estimate is:

$$\begin{aligned} log(\hat{I}_{i,t}) &= \varphi log(h_{i,t}) + c_0 + c_1 Age_{i,t} + c_2 Male_i + c_3 Grade_i + c_4 Couple_{i,t} + c_5 Smoke_{i,t} \\ &\quad + c_6 Drink_{i,t} + c_7 doctor_{i,t} + c_8 Patient_{i,t} + c_9 Tpatient_{i,t} \\ &\quad + c_{10} Hnights_{i,t} + \sum_{j=1,J-1} a_j Country_i^j + \epsilon_{i,t} \qquad (17) \\ \epsilon_{i,t} &= \eta_i + \zeta_{it} \end{aligned}$$

Estimations results are in Table 3. Note that only the waves 2 and 5 have been used in this estimation. This is due to the fact that health expenditures are not available at wave 4. Also, due to the dynamic structure of the Equation 3.1, $\hat{I}_{i,t}$ is not available for wave 1.

Most of our estimated coefficients have the expected signs. We find a positive and significant elasticity of health expenditures. This is an interesting result. Most of time, a positive relationship is found between health expenditures and health status, at the agggregate level. At the microeconomic level, the relationship appears to be negative because the worse is your health status, the more you spend for health. But these results hold for health as a stock. Here, $\hat{I}$ is a flow of health. As a result, our results suggest that higher individual health expenditures (h_{it}) imply higher health flows $\hat{I}_{it}$.

Individual characteristics also affect the health production function. Being in couple reduces significantly health investment. We also find a weak evidence (significant at 10% level) that male invests more than female. But, contrarily to Wagstaff (2002), we find that ageing has a positive and significant effect on health investment. This denotes that older invest more than younger in health care.Except for individuals with no school grade, the higher the school grade is, the lower the demand for health care is. However, for individual with no school grade, we find a weak evidence that the demand for health care is higher than that of individual with graduate studies level. Contrarily to Grossman (1999) and Wagstaff (2002), our specification gives an effect of education that is consistent with the original health investment model (Grossman, 1972). Turning to behavioural variables, we can see that drinking alcohol has no significant effect on health investment. However, smoking increases the demand for health care. Seeing doctor or being patient increase the health investment but the frequency of being patient and the total nights in hospital decrease the health investment.

Table 3: Health production function estimation

Variable	Coefficients	Variable	Coefficients
Log of health expenditures	0.000057*** (0.00002)	Country	ref: Estonia
Age	0.00011*** ($6.46e-6$)	Austria	−0.00008 (0.00018)
Male	0.00013* (0.00007)	Germany	0.0024*** (0.0002)
Couple	−0.0003*** (0.000089)	Sweden	0.00135*** (0.00017)
Ever smoke	0.00016** (0.00007)	Netherlands	0.00136*** (0.00018)
Drink alcohol	0.00012 (0.00009)	Spain	0.00168*** (0.0002)
Doctor	0.00006*** ($5.05e-6$)	Italy	0.00063*** (0.00019)
Be patient	0.00043** (0.00018)	France	0.00033** (0.00017)
Times being patient	−0.00042*** (0.00009)	Denmark	0.00088*** (0.00017)
Nights in hospital	−0.00002** ($9.42e-6$)	Greece	−0.00001 (0.00023)
Grade	ref: graduate studies	Switzerland	0.00068*** (0.00017)
no grade	−0.00025* (0.00013)	Belgium	0.00011 (0.00016)
college degree	0.00028*** (0.00008)	Israel	−0.00237*** (0.00018)
undergraduate studies	−0.00014 (0.00017)	Czech Republic	0.00135*** (0.00019)
Intercept	−0.00667*** (0.00042)	Slovenia	0.00029 (0.00029)
$\sigma_\mu = 3.5e-5$, $\sigma_e = 0.0124$			

***: significant at 1% level, **: significant at 5% level, *: significant at 10% level, Standard errors are in parenthesis.

For the health consumption function, we assume that each worker uses a share of is health stock as an input to earn a wage at the end of an production process. Thus, we assume wage (W) to be a function of health:

$$\bar{H}_{i,t} = g\Big((1-\omega)W_{i,t}\Big) = A_{1,i}\Big((1-\omega)W_{i,t}\Big)^{\theta} \tag{18}$$

where $\bar{H}_{i,t}$ denotes the health depreciation due to job status (the health stock used to earn a wage that is the difference between the wage earned and the retirement pension), and $A_{1,i}$ includes controls.

The health depreciation $\bar{H}_{i,t}$ due to job status is decomposed as follows:

$$\bar{H}_{i,t} \quad = \quad \alpha_w Work_{i,t} + \alpha_c C_{i,t} * Work_{i,t} \tag{19}$$

Thus, the impact of job status on total health depreciation $\hat{\hat{\delta}}_{i,t}$ is:

$$\begin{aligned} \hat{\hat{\delta}}_{i,t} &= \alpha_w Work_{i,t} + \alpha_c C_{i,t} * Work_{i,t} + \alpha_3 Age_{i,t} + \alpha_4 H_{i,t} \\ &\quad + \sum_{j=1,J-1} b_j Country_i^j + u_{i,t}^{\delta} \qquad (20) \\ u_{i,t}^{\delta} &= \eta_i + \zeta_{it} \end{aligned}$$

where $u_{i,t}^{\delta}$ are error terms, $Work_{i,t}$ is a dummy that is one if individual i works at t, and $\hat{\hat{\delta}}_{i,t}$ is provided by the estimated state-space model. We include country dummies to account for country heterogeneity in terms of working conditions. Due to the fact that the dataset covers only aged workers, the age square effect is not significant. Thus, we exclude the square of age in the estimated model.

Estimations results are in Table 4. Estimated coefficients have the expected signs. We find a strong evidence that health depreciation is higher for workers and that the better the working condition is, the lower the health depreciation is. That is a strong result and it is consistent with previous literature (Debrand and Blanchet, 2008). We also find a positive and significant effect of ageing on health depreciation. The higher the health stock is, the higher the health depreciation is. This finding denotes that a health shock has an higher marginal effect on healthier.

Table 4: Health depreciation explanatory factors

Variable	Coefficient	Variable	Coefficient
Work	0.0037*** (0.00064)	Country	Ref = Estonia
Work*Condition	−0.00097*** (0.00017)	Austria	−0.0076*** (0.00057)
Age	0.00009*** (0.00002)	Germany	−0.00847*** (0.00055)
Health stock	0.00557*** (0.00016)	Sweden	−0.01133*** (0.00053)
		Netherlands	−0.00951*** (0.00052)
		Spain	−0.00672*** (0.00055)
		Italy	−0.00662*** (0.00054)
		France	−0.00588*** (0.00048)
		Denmark	−0.01137*** (0.00054)
		Greece	−0.00957*** (0.00074)
		Switzerland	−0.01049*** (0.00054)
		Belgium	−0.0079*** (0.0005)
		Israel	−0.0033*** (0.00057)
		Czech Republic	−0.0052*** (0.00053)
		Poland	−0.00051*** (0.00094)
Intercept	−0.05446*** (0.00215)	Slovenia	−0.00455*** (0.00087)
$\sigma_\mu = 0.7e - 5$, $\sigma_e = 0.0138$			

***: significant at 1% level, **: significant at 5% level

Standard errors are in parenthesis.

The log-linear form of the health consumption function to be estimated is:

$$\begin{aligned} log(\bar{H}_{i,t}) &= \theta log\big[(1-\omega)W_{i,t}\big] + b_0 + b_1 Age_{i,t} \\ &\quad + b_2 Male_i + b_3 Grade_i + \sum_{j=1,J-1} d_j Country_i^j + \xi_{i,t}^w \\ \xi_{i,t}^w &= \eta_i + \zeta_{it} \end{aligned} \tag{21}$$

The proportion of missing data for the percentage of salary to receive as pension is large (around 39%). Neglecting workers for who this variable is missing will considerably drop our estimate sample as this variable is important for the early retirement probabilities computation. Thus, we complete an imputation technique to predict these missing values. For the sample on which the percentage of salary to receive as pension is observed, we estimate a model that explain the later variable with observed individual characteristics such as school grade, salary and country dummies that account for pension regulation across countries. The results of the estimated model for imputation are in Table 19 in appendix 6.

The estimation results of health depreciation function are in Table 5. The estimated coefficients have the expected signs. The health depreciation due to working condition is higher for male and the lower the pension share and the school level are, the higher the depreciation due to working condition is. This denotes that as workers with lower school level have job with low security, high physical pressure and low working condition, then the effect of job on their health is higher.

Table 5: Health consumption function

Variable	Coefficient	Variable	Coefficient
Wage: $log\big[(1-\omega)W_{i,t}\big]$	0.00015^{***} $(3.89e{-}6)$	country	ref: Estonia
age	-0.00052^{***} $(2.6e{-}6)$	Austria	-0.00225^{***} (0.00008)
male	0.00091^{***} (0.00003)	Germany	0.00019^{**} (0.00008)
Grade	ref: graduate studies	Sweden	-0.00094^{***} (0.00007)
no grade	0.00288^{***} (0.00005)	Netherlands	-0.00168^{***} (0.00007)
college degree	0.00165^{***} (0.00003)	Spain	-0.00062^{***} (0.00008)
undergraduate studies	0.00274^{***} (0.00005)	Italy	0.00045^{***} (0.00008)
		France	-0.00045^{***} (0.00007)
		Denmark	-0.00256^{***} (0.00007)
		Greece	0.00345^{***} (0.0001)
		Switzerland	-0.00274^{***} (0.00007)
		Belgium	-0.00135^{***} (0.00007)
		Israel	0.0004^{***} (0.00009)
		Czech Republic	-0.00032^{***} (0.00008)
		Slovenia	-0.00193^{***} (0.00012)
Intercept	0.0326^{***} (0.00017)	Poland	0.00261^{***} (0.00013)
$\sigma_\mu = 0.0229$, $\sigma_e = 0.0054$, $\rho = 0.1524$			

***: significant at 1% level, **: significant at 5% level, Standard errors are in parenthesis.

3.3 Estimation of utility functions parameters

The estimation utility functions parameters in Equation 5 is based on the approach used by Hall and Jones (2007). The estimation of the parameters γ, λ, and a is done by following three steps:

- Estimate QALY for all available diseases in each country for cohorts of individual. In our paper, we use four cohorts of individuals in each country: individuals aged 50 to 59 years old, 60 to 64 years old, 65 to 74 years old, and over 75 years old. In each ordered probit regression, we include reported diseases and some demographic characteristics.
- For each estimation done in the previous step, by country, we keep only QALY that are significant in each cohort and are decreasing by age. We also estimate with the SHARE dataset, the average value of estate by country and age group. Then we use data from mortality table (from EuroStat database and Israel national statistics bureau) to compute the age-specific state of health by age group.
- The last step consists in solving the following non linear equations:

$$\frac{u(H_{50-59}, E_{50-59})}{Q_{50-59}} = \frac{u(H_{60-64}, E_{60-64})}{Q_{60-64}} = \frac{u(H_{65-74}, E_{65-74})}{Q_{65-74}} = \frac{u(H_{75+}, E_{75+})}{Q_{75+}}$$

The estimated parameters are provided by country in Table 6.

Table 6: Utility functions parameters (with SHARE)

Country	Separable function		
	γ	λ	a
Austria	1.105350	2.120083	0.000162
Germany	1.282327	2.167405	0.000266
Sweden	1.235924	2.165392	0.0002
Netherlands	1.341981	2.167014	0.000344
Spain	1.241212	2.314658	0.000179
Italy	1.240786	2.134855	0.000204
France	1.484212	2.114771	0.000327
Denmark	1.169949	2.082954	0.000190
Greece	1.254943	2.535495	0.000136
Switzerland	1.051630	1.965825	0.000201
Belgium	1.210802	2.182727	0.000069
Israel	1.201668	2.245111	0.000459
Czech Republic	1.151662	2.228266	0.000160
Poland	1.308289	2.449786	0.000462
Slovenia	1.029674	1.888861	0.000464
Estonia	1.023071	2.058305	0.000152

3.4 Estimation of retirement probabilities

In this section, we are now ready to present our calculated discount factor and early retirement probabilities computed using a separable utility function. The computation of $r_{i,t}$ and $p_{i,t}$ at the date t involves the use of the health stock at $t+1$ and the dynamic of estate from $t+1$ until worker dies[11]. Health stock at $t+1$ is known with the individual characteristics at t. For estate equation, earnings after retirement are given by a share of annual salary received as pension. The remaining estate value after expenditures at t is supposed to be appreciated at the interest rate in the country. For the expenditures level after retirement, many papers address these issues. We use the results of Fisher et al (2005) who find in their research that consumption expenditures decline by 2.5% at the retirement and by 1% per year after retirement.

Statistics on preferences for future are provided in Table 7. The preference for future across elder workers in Europe is highly volatile. On average, 66.56% of aged workers in Europe have a low preference for future (on average, $r_{i,t} = 0.16755$ with a standard deviation of 0.23963). However it exists high volatility across countries. In countries such as Germany, France, Netherlands, Spain, Greece, Israel and Poland, at least 70% of aged workers have a low preference for future while in countries such Estonia, Switzerland and Slovenia, less than 50% of aged workers have a low preference for future. Individual preference for future can also be higher than one (for 33.44% of the estimation sample). These individuals are characterized by a relatively high health stock but a very low estate value. Thus, for them, as they expect a long and healthier time to live, their hope on future is high because, in addition to the pension they will have at retire, they can continue working to earn additional income that will increase their estate and then, their utility.

[11]The individual survival is assumed to be the life expectancy at his age in his country.

Table 7: Preference for future across European countries

Country	Population	Low ($r_{i,t} < 1$)		High ($r_{i,t} > 1$)	
	Proportion(in%)	%	*Average*	%	*Average*
Austria	4.61	2.76	0.21301 (0.25814)	1.85	464.62 (3273.347)
Germany	5.3	3.74	0.17314 (0.22755)	1.55	459.2 (3404.512)
Sweden	10.08	5.86	0.21836 (0.24735)	4.22	290.5 (2330.292)
Netherlands	8.18	7.07	0.09752 (0.19306)	1.11	699.77 (5019.927)
Spain	4.94	4.3	0.0996 (0.19075)	0.64	548.74 (3734.307)
Italy	5.08	3.02	0.21695 (0.27218)	2.06	478.17 (4380.884)
France	9.6	7.52	0.12266 (0.21442)	2.08	494.25 (3997.869)
Denmark	10.08	5.91	0.20999 (0.25577)	4.17	141.21 (1661.173)
Greece	5.54	5.13	0.06239 (0.14002)	0.41	344.96 (2921.652)
Switzerland	7.54	3.23	0.25173 (0.28794)	4.31	777.1 (5364.31)
Belgium	10.97	6.92	0.25032 (0.26481)	4.05	578.78 (4729.252)
Israel	6.37	5.63	0.0999 (0.18414)	0.74	233.66 (2226.619)
Czech Republic	4.66	2.87	0.23729 (0.26131)	1.79	301.56 (2377.2)
Poland	1.23	0.89	0.1345 (0.2069)	0.34	717.75 (4591.578)
Slovenia	1.22	0.61	0.20732 (0.2578)	0.61	132.84 (909.072)
Estonia	4.61	1.08	0.31709 (0.28705)	3.52	697.69 (4723.899)
Overall (Obs.: 20,782)	100	66.56	0.16755 (0.23963)	33.44	474.09 (3871.625)

Standard deviations are in parenthesis

From descriptive statistics presented in Table 8, significant differences are observed among groups. Workers that choose early retirement have the highest health stock, and the lowest estate value and the lowest preference for future. In contrast, workers that do not choose early retirement have the lowest health stock but the highest estate value and the highest preference for future.

Table 8: Characterization of early retirement across European countries

Groups	Mean $r_{i,t}$	Mean Estate	Mean health
Choose early retire	1.4919 (0.2309)	$272,366.9$ (1,664.55)	10.2172 (0.0045)
Not choose early retirement	104.63 (6.9529)	$471,223.2$ (3,626.88)	10.0358 (0.0033)
Difference	-103.14^{***} (10.4074)	$-198,856.3^{***}$ (5,541.59)	0.1814^{***} (0.0058)
Choose early retire	1.4929 (0.2309)	$272,366.9$ (1,664.55)	10.2172 (0.0045)
Uncertain early retirement	66.1737 (5.2808)	$325,090.7$ (2,861.81)	10.0895 (0.0037)
Difference	-64.6808^{***} (6.9698)	$-52,723.85^{***}$ (3,982.18)	0.1277^{***} (0.0059)
Uncertain early retirement	66.1737 (5.2808)	$325,090.7$ (2,861.81)	10.0895 (0.0037)
Not choose early retirement	104.63 (6.9529)	$471,223.2$ (3,626.88)	10.0358 (0.0033)
Difference	-38.4548^{***} (9.1584)	$-146,132.5^{***}$ (4,825.58)	0.0537^{***} (0.005)

***: significant at 1% level. Standard errors are in parenthesis.

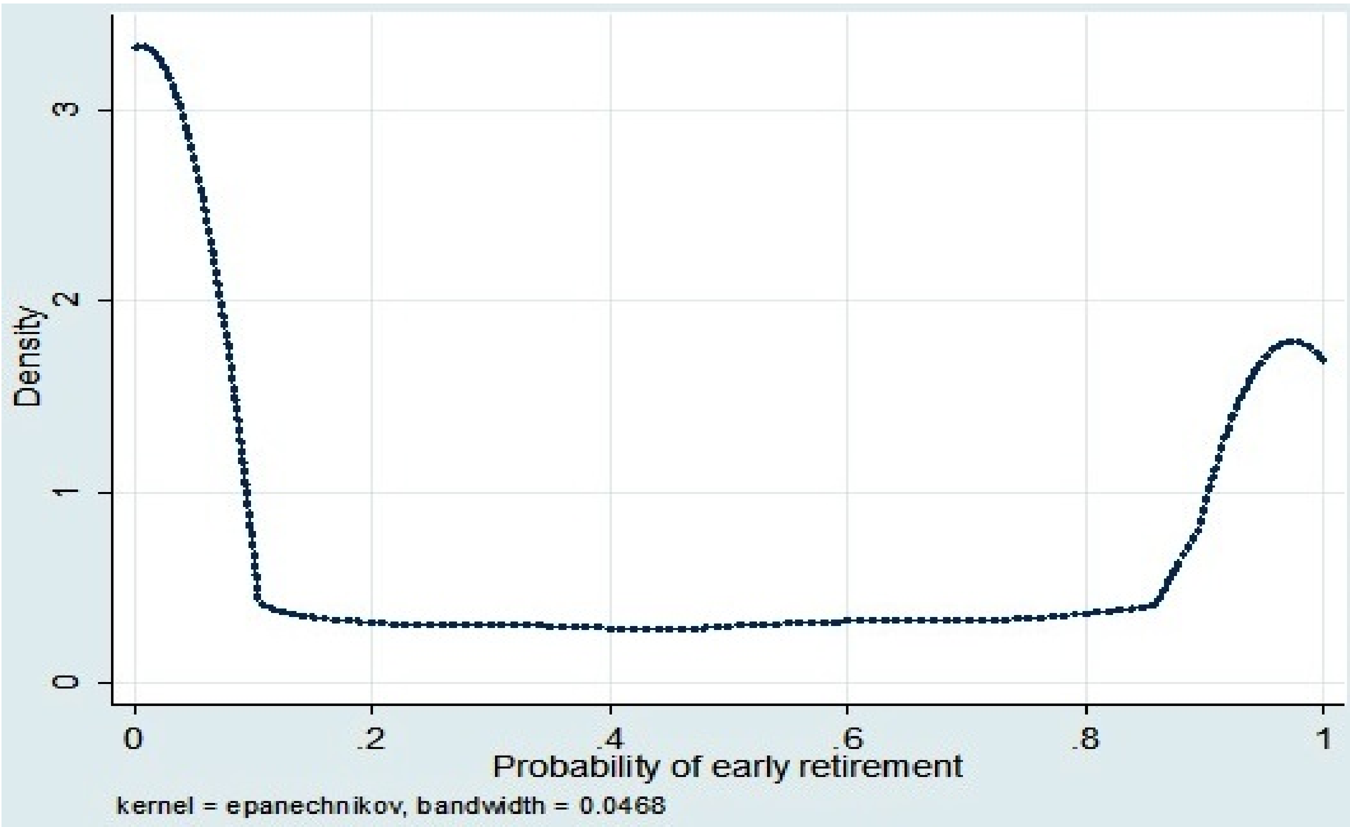

Figure 2: Density of early retirement probability

3.5 Robustness analysis

The robustness check for our model will consist in showing the ability of our model to distinguish between two groups of individual across workers with uncertainty about their early retirement decision. For that purpose, we plot the density of the estimated early retirement probability for workers with uncertainty about early retirement. The plotted density is shown in Figure 2. As we can see, the density has two peaks, the first one around the early retirement probability of 0.07 that is the higher and second one around the early retirement probability of 0.95 that is the lower peak. In addition, early retirement probability values between 0.1 and 0.85 have lower and closer to zero densities. This plot gives a first level of validation of the accuracy of our model.

This illustrates the ability of our model to create two groups: one with a strong probability at time $t-1$ to retire and one with a strong probability at time $t-1$ not to retire. Table 9 gives sizes of the corresponding populations. Around 80% of the population is within one of the two extreme groups.

Table 9: Individual probabilities of retirement

	N	%
$\hat{p}_{i,t-1} > 0.85$	$10,213$	28.11
$0.15 \leq \hat{p}_{i,t-1} \leq 0.85$	$8,127$	22.37
$\hat{p}_{i,t-1} < 0.15$	$17,990$	49.52

The second robustness check test we do is to test the relationship between the calculated early retirement probability and the transition from work to early retirement. For that purpose, we estimate a dynamic probit model with the transition from work to early retirement as dependant variable. We estimate 3 models: the first one with only the last period early retirement probability as explanatory variable, the second one by including school grade that account for the post retirement opportunities, and the third one by including country dummies and school grade to account for country heterogeneities in terms of retirement policy and in terms of job opportunities after retirement. The estimated model is given by:

$$\begin{cases} ER^*_{i,t} = d_0 + d_1\hat{p}_{i,t-1} + d_2 grade_i + d_3 country_i + \epsilon_{i,t} \\ ER_{i,t} = 1 \ \ if \ \ ER^*_{i,t} > 0 \end{cases}$$

Where $ER_{i,t}$ is 1 if individual i retires earlier at t. Thus, the calculated early retirement probability is related with early retirement if d_1 is significantly different from zero. Estimate results of this model in Table 10. As we can see, in all estimated models, the calculated early retirement probability and the calculated early retirement status are related with the transition from work to early retirement. These links remain significant when we control for school level and country heterogeneity. These findings strengthen the reliability of our approach and our computed early retirement probabilities.

Last point to consider is Table 1. There is a wide gap between the declaration of individuals which are asked if they intend to retire at the next period and the real choice of individuals. Over the three waves, only 22.7% of individuals who declare that they want to retire at the next period do retire, at the next period. For individuals who declare that they do not want to retire, the corresponding ration is 17.7%.

Table 10: Relationships between calculated early retirement probability and early retirement

Transition from work to early retirement	Model 1	Model 2	Model 3
$p_{i,t-1}$	0.0899*** (0.0264)	0.089*** (0.0265)	0.0857*** (0.0308)
Grade	Ref = Graduate studies		
No grade	–	−0.0203 (0.0399)	0.0769* (0.0418)
College degree	–	0.154*** (0.0277)	0.1673*** (0.0287)
Undergraduate studies	–	0.0088 (0.0385)	−0.0029 (0.0402)
Intercept	−1.1968*** (0.0172)	−1.2666*** (0.0255)	−1.0694*** (0.077)
Country fix effects	NO	NO	YES

***: significant at 1% level; *: significant at 10% level. Standard errors are in parenthesis.

It turns out that it is difficult to confront an individual predicted probability (at a given time period) to the corresponding real individual action which happens latter. This gap is due to two main factors:

- the time gap between individual interviews and the time of individual decisions.
- People can express wishes or preferences which can be very different from actions.

From Table 11, we can see that, finally, our predicted probability is quite better than the individual declaration to assess the real choice of individuals. Over the three waves, we find that 36.92% of those with retirement probability higher than 0.85 retire next period and only 5.72% of those with retirement probability lower than 0.15 retire next period.

Table 11: Individual retirement status according to past $\hat{p}_{i,t-1}$ values

	%
$\hat{p}_{i,t-1} > 0.85$	36.92
$0.15 \leq \hat{p}_{i,t-1} \leq 0.85$	10.74
$\hat{p}_{i,t-1} < 0.15$	5.72

Conclusion

This paper analyzes the early retirement decision-making process among older workers in Europe. Several previous papers focus on this issue by analyzing the health effects, financial effects, or both. Some papers highlight the important roles of worker's environment and institutional regulations. However, these previous papers use a binary outcome model to assess the effects of those key variables on the probability to retire earlier. In our approach, we specify a worker's utility function depending on his or her health, estate, institutional framework by the use of the share of salary as pension, and preference for future. This specification allows us to assess the early retirement decision-making process by accounting for, not only the current health condition and estate value, but for the whole discounted lifetime utility. Estimations are done with four waves of the SHARE dataset.

Our framework is innovative. We estimate health investment and health depreciation from the Grossman's model using a space-state approach and we use these estimations to estimate a health production and health consumption function that are key in early retirement decision-making process. Contrarily to previous literature on demand for health care equation, this approach lead to expected signs for all determinants.

From our model, we predict for each individual and at each period, the probability that workers retire early with regards to their financial, health and socioeconomics conditions. These early retirement probabilities are function of (i) the marginal productivity of health expenditures, (ii) the marginal health depreciation due to working condition, and (iii) the discounted future marginal utility of estate divided by the current marginal utility of health. We show that our approach is robust as it disentangles between three categories of workers: those who will not choose early retirement, those who will choose early retirement, and those who are uncertain about early retirement. We also show that our calculated early retirement probabilities are good predictors of observed individual early retirement. Finally, this framework allows us to investigate on the effects of public policies such as (i) predicting, by simulations, the probability of early retirement with respect to health, estate value, and pension share, and (ii) predicting how public health policy or retirement policies may affect retirement behaviour.

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Appendices

Appendix 1: Log-likelihood derivation

This section aims to show details of the calculation of the straightforward form of the likelihood function used for the maximization algorithm. Note that as the measurement variable $h_{i,t}$ is a unidimensional vector, the matrix $M_{i,t/t-1}$ is a scalar.

$$
\begin{aligned}
L_i &= \int_{\mathbb{R}} \phi_{\sigma_1}(\xi_i^1) \prod_{t=1}^{T} \frac{1}{\sqrt{2\,\pi det(M_{i,t/t-1})}} exp\big(-\frac{1}{2}\,(h_{i,t}-\xi_i^1)\, M_{i,t/t-1}^{-1}\,(h_{i,t}-\xi_i^1)'\big)\, d\xi_i^1 \\
&= \frac{1}{\sigma_1\sqrt{2\pi}} \prod_{t=1}^{T} \frac{1}{\sqrt{2\,\pi det(M_{i,t/t-1})}} \int_{\mathbb{R}} exp\Big(-\frac{1}{2}\Big[\sum_{t=1}^{T} M_{i,t/t-1}^{-1}\,(h_{i,t}-\xi_i^1)^2 + (\frac{\xi_i^1}{\sigma_1})^2\Big]\Big)\, d\xi_i^1 \\
&= \frac{1}{\sigma_1\sqrt{2\pi}} \prod_{t=1}^{T} \frac{1}{\sqrt{2\,\pi det(M_{i,t/t-1})}} exp\Big(-\frac{1}{2}\sum_{t=1}^{T} M_{i,t/t-1}^{-1} h_{i,t}^2\Big) * \\
&\quad \int_{\mathbb{R}} exp\Big(-\frac{1}{2}\Big[\Big(\sum_{t=1}^{T} M_{i,t/t-1}^{-1} + \frac{1}{\sigma_1^2}\Big)(\xi_i^1)^2 - 2\xi_i^1 \sum_{t=1}^{T} M_{i,t/t-1}^{-1} h_{i,t}\Big]\Big)\, d\xi_i^1 \\
&= \frac{1}{\sigma_1\sqrt{2\pi}} \prod_{t=1}^{T} \frac{1}{\sqrt{2\,\pi det(M_{i,t/t-1})}} exp\Big(-\frac{1}{2}\sum_{t=1}^{T} M_{i,t/t-1}^{-1} h_{i,t}^2\Big) exp\Big(\frac{\big(\sum_{t=1}^{T} M_{i,t/t-1}^{-1}\, h_{i,t}\big)^2}{2(\frac{1}{\sigma_1^2} + \sum_{t=1}^{T} M_{i,t/t-1}^{-1})}\Big) * \\
&\quad \int_{\mathbb{R}} exp\Big(-\frac{1}{2}\Big[\Big(\sum_{t=1}^{T} M_{i,t/t-1}^{-1} + \frac{1}{\sigma_1^2}\Big)\Big(\xi_i^1 - \frac{\sum_{t=1}^{T} M_{i,t/t-1}^{-1} h_{i,t}}{\sum_{t=1}^{T} M_{i,t/t-1}^{-1} + \frac{1}{\sigma_1^2}}\Big)^2\Big]\Big)\, d\xi_i^1 \\
&= \frac{1}{\sqrt{1+\sigma_1^2 \sum_{t=1}^{T} M_{i,t/t-1}^{-1}}} \prod_{t=1}^{T} \Big(\frac{1}{\sqrt{2\,\pi det(M_{i,t/t-1})}}\Big) exp\Big(-\frac{1}{2}\sum_{t=1}^{T} M_{i,t/t-1}^{-1} h_{i,t}^2\Big)\, exp\Big(\frac{\big(\sum_{t=1}^{T} M_{i,t/t-1}^{-1}\, h_{i,t}\big)^2}{2(\frac{1}{\sigma_1^2} + \sum_{t=1}^{T} M_{i,t/t-1}^{-1})}\Big)
\end{aligned}
$$

The link between the last two equalities is established by the use of the following relationship (Gauss integral):

$$\int_{\mathbb{R}} exp\Big(-a(x-b)^2\Big)dx = \int_{\mathbb{R}} exp\Big(-ay^2\Big)dy = \sqrt{\frac{\pi}{a}}$$

Appendix 2: Kalman filter derivation

In this section, we present details of calculation of the Kalman filter's tools applied on the following state-space model matrix representation:

$$\begin{aligned} H_{i,t} &= B_{i,t-1}\Gamma_{i,t-1} + H_{i,t-1} + \xi_{i,t}, \forall t \geqslant 1 \\ \Gamma_{i,t-1} &= A_1\Gamma_{i,t-2} + A_0 + \Xi_{i,t-1}, \forall t \geqslant 2 \end{aligned}$$

The calculations are inspired by the chapter 11 of the book of Droesbeke et al (2013). We start with the notations below:

$$\begin{cases} (a_1)\, \hat{\Gamma}_{i,t-1/t} = E(\Gamma_{i,t-1}/H_{i,1}, ..., H_{i,t}) \\ (a_2)\, \Sigma_{i,t-1/t} = V(\Gamma_{i,t-1}/H_{i,1}, ..., H_{i,t}) \\ (b_1)\ \ \hat{\Gamma}_{i,t/t} = E(\Gamma_{i,t}/H_{i,1}, ..., H_{i,t}) \\ (b_2)\ \ \Sigma_{i,t/t} = V(\Gamma_{i,t}/H_{i,1}, ..., H_{i,t}) \\ (c_1)\, \hat{H}_{i,t/t-1} = E(H_{i,t}/H_{i,1}, ..., H_{i,t-1}) \\ (c_1)\, M_{i,t/t-1} = V(H_{i,t}/H_{i,1}, ..., H_{i,t-1}) \\ \qquad Q_t = V(\Xi_{i,t}) = \Sigma_\Xi \\ \qquad R_t = V(\xi_{i,t}) = \sigma_1^2 + \sigma_2^2 \end{cases}$$

The first step consists of the calculation of (a_1) and (a_2). The probability distribution function ℓ of $\left(\Gamma_{i,t-1}/H_{i,1}, ..., H_{i,t-1}\right)$ is (recurrence hypothesis):

$$\ell(\Gamma_{i,t-1}/H_{i,1}, ..., H_{i,t-1}) \quad = \quad N(\hat{\Gamma}_{i,t-1/t-1}, \Sigma_{i,t-1/t-1})$$

And the probability distribution function of $H_{i,t}/\Gamma_{i,t-1}, H_{i,1}, ..., H_{i,t-1}$ is:

$$\ell(H_{i,t}/\Gamma_{i,t-1}, H_{i,1}, ..., H_{i,t-1}) \quad = \quad N(B_{i,t-1}\Gamma_{i,t-1} + H_{i,t-1}, R_t)$$

As $B_{i,t-1}\Gamma_{i,t-1} + H_{i,t-1} = B_{i,t-1}\hat{\Gamma}_{i,t-1/t-1} + H_{i,t-1} + B_{i,t-1}(\Gamma_{i,t-1} - \hat{\Gamma}_{i,t-1/t-1})$, where $B\hat{\Gamma}_{i,t-1/t-1} + H_{i,t-1}$ denotes the mean of $\left(H_{i,t}/H_{i,1}, ..., H_{i,t-1}\right)$, and by using the theorem 1 in chapter 11 of the book of Droesbeke et al (2013), we can deduce the probability distribution function of $\left(H_{i,t}, \Gamma_{i,t-1}/H_{i,1}, ..., H_{i,t-1}\right)$ as:

$$\ell(H_{i,t}, \Gamma_{i,t-1}/H_{i,1}, ..., H_{i,t-1}) \quad = \quad N(m_{H,\Gamma}, V_{H,\Gamma})$$

Where $m_{H,\Gamma} = \begin{pmatrix} B_{i,t-1}\Gamma_{i,t-\hat{1}/t-1} + H_{i,t-1} \\ \hat{\Gamma}_{i,t-1/t-1} \end{pmatrix}$, and $V_{H,\Gamma} = \begin{pmatrix} R_t + B_{i,t-1}\Sigma_{i,t-1/t-1}B' & B_{i,t-1}\Sigma_{i,t-1/t-1} \\ \Sigma_{i,t-1/t-1}B'_{i,t-1} & \Sigma_{i,t-1/t-1} \end{pmatrix}$. Thus, by using the theorem 2 in chapter 11 of the book of Droesbeke et al (2013), we can deduce explicit forms of (a_1) and (a_2) as:

$$\begin{aligned} \hat{\Gamma}_{i,t-1/t} &= \hat{\Gamma}_{i,t-1/t-1} + \Sigma_{i,t-1/t-1}B'_{i,t-1}(R_t + B_{i,t-1}\Sigma_{i,t-1/t-1}B'_{i,t-1})^{-1}(H_{i,t} - B_{i,t-1}\hat{\Gamma}_{i,t-1/t-1} - H_{i,t-1}) \\ \Sigma_{i,t-1/t} &= \Sigma_{i,t-1/t-1} - \Sigma_{i,t-1/t-1}B'_{i,t-1}(R_t + B_{i,t-1}\Sigma_{i,t-1/t-1}B'_{i,t-1})^{-1}B_{i,t-1}\Sigma_{i,t-1/t-1} \end{aligned}$$

For terms in (b_1) and (b_2), we start by calculating the probability distribution function of $\left(\Gamma_{i,t-1}/H_{i,1}, ..., H_{i,t}\right)$ and $\left(\Gamma_{i,t-1}/H_{i,1}, ..., H_{i,t}\right)$. They are:

$$\begin{aligned} \ell(\Gamma_{i,t-1}/H_{i,1}, ..., H_{i,t}) &= N(\hat{\Gamma}_{i,t-1/t}, \Sigma_{i,t-1/t}) \\ \ell(\Gamma_{i,t}/\Gamma_{i,t-1}, H_{i,1}, ..., H_{i,t}) &= N(A_0 + A_1\Gamma_{i,t-1}, Q_t) \end{aligned}$$

Here too, we use the theorem 1 and the fact that $A_0 + A_1\Gamma_{i,t-1} = A_0 + A_1\hat{\Gamma}_{i,t-1/t} + A_1(\Gamma_{i,t-1} - \hat{\Gamma}_{i,t-1/t})$ to deduce the probability distribution function of $\left(\Gamma_{i,t-1}, \Gamma_{i,t}/H_{i,1}, ..., H_{i,t}\right)$ as:

$$\ell(\Gamma_{i,t-1}, \Gamma_{i,t}/H_{i,1}, ..., H_{i,t}) = N(m_{\Gamma_t,\Gamma_{t-1}}, V_{\Gamma_t,\Gamma_{t-1}})$$

Where $m_{\Gamma_t,\Gamma_{t-1}} = \begin{pmatrix} \hat{\Gamma}_{i,t-1/t} \\ A_0 + A_1\hat{\Gamma}_{i,t-1/t} \end{pmatrix}$, and $V_{\Gamma_t,\Gamma_{t-1}} = \begin{pmatrix} \Sigma_{i,t-1/t} & \Sigma_{i,t-1/t}A'_1 \\ A_1\Sigma_{i,t-1/t} & Q_t + A_1\Sigma_{i,t-1/t}A'_1 \end{pmatrix}$. Then we can deduce explicit forms of (b_1) and (b_2) as (and this relation proves the recurrence hypothesis):

$$\begin{aligned} \hat{\Gamma}_{i,t/t} &= A_0 + A_1\hat{\Gamma}_{i,t-1/t} \\ \Sigma_{i,t/t} &= Q_t + A_1\Sigma_{i,t-1/t}A'_1 \end{aligned}$$

Then we can deduce explicit forms of (c_1) and (c_2) by using the derived probability distribution function of $\left(H_{i,t}, \Gamma_{i,t-1}/H_{i,1}, ..., H_{i,t-1}\right)$ as:

$$\begin{aligned} \hat{H}_{i,t/t-1} &= B_{i,t-1}\hat{\Gamma}_{i,t-1/t-1} + H_{i,t-1} \\ M_{i,t/t-1} &= R_t + B_{i,t-1}\Sigma_{i,t-1/t-1}B'_{i,t-1} \end{aligned}$$

When we apply the Kalman filter to our model, we obtain the following estimation for parameters:

$$
\begin{cases}
\hat{\Gamma}_{i,t-1/t} = \hat{\Gamma}_{i,t-1/t-1} + \Sigma_{i,t-1/t-1} B'_{i,t-1} (R_t + B_{i,t-1} \Sigma_{i,t-1/t-1} B'_{i,t-1})^{-1} (H_{i,t} - B_{i,t-1} \hat{\Gamma}_{i,t-1/t-1} - H_{i,t-1}) \\
\Sigma_{i,t-1/t} = \Sigma_{i,t-1/t-1} - \Sigma_{i,t-1/t-1} B'_{i,t-1} (R_t + B_{i,t-1} \Sigma_{i,t-1/t-1} B'_{i,t-1})^{-1} B_{i,t-1} \Sigma_{i,t-1/t-1} \\
\hat{\Gamma}_{i,t/t} = A_0 + A_1 \hat{\Gamma}_{i,t-1/t} \\
\Sigma_{i,t/t} = Q_t + A_1 \Sigma_{i,t-1/t} A'_1 \\
\hat{H}_{i,t/t-1} = B_{i,t-1} \hat{\Gamma}_{i,t-1/t-1} + H_{i,t-1} \\
M_{i,t/t-1} = R_t + B_{i,t-1} \Sigma_{i,t-1/t-1} B'_{i,t-1}
\end{cases}
$$

Appendix 3: Estimation of health stock and working condition indicators

Table 12: Ordered probit estimates of health

Variables+	Coefficients	Variables	Coefficients	Variables	Coefficients
Heart attack	-0.5448^{***} (0.0125)	Sad or depressed	-0.1651^{***} (0.0088)	Germany	-0.3083^{***} (0.0277)
Hypertension	-0.2924^{***} (0.0088)	No hopes for future	-0.2195^{***} (0.0106)	Sweden	0.4359^{***} (0.0254)
Cholesterol	-0.0884^{***} (0.0096)	Rather be dead	-0.2663^{***} (0.0157)	Netherlands	0.0566^{**} (0.0247)
Stroke	-0.6507^{***} (0.0209)	Trouble sleeping	-0.233^{***} (0.0086)	Spain	-0.3816^{***} (0.0244)
Diabetes	-0.5315^{***} (0.0134)	Less interest in things	-0.1589^{***} (0.0142)	Italy	-0.2341^{***} (0.0242)
Lung disease	-0.559^{***} (0.017)	Irritability	-0.0698^{***} (0.0089)	France	-0.0942^{***} (0.0221)
Arthritis	-0.435^{***} (0.0101)	Lost of appetite	-0.3035^{***} (0.0143)	Denmark	0.5837^{***} (0.026)
Osteoporosis	-0.3641^{***} (0.0126)	Fatigue	-0.4051^{***} (0.0085)	Greece	0.2173^{***} (0.0288)
Cancer	-0.5786^{***} (0.0183)	No conc. in entertainment	-0.1418^{***} (0.0131)	Switzerland	0.3581^{***} (0.0251)
Ulcer	-0.1946^{***} (0.018)	No conc. in reading	-0.1537^{***} (0.0126)	Belgium	0.1542^{***} (0.022)
Parkinson disease	-1.1373^{***} (0.0496)	No enjoyment	-0.1636^{***} (0.0114)	Israel	-0.0481^{*} (0.0278)
Cataract	-0.0354^{**} (0.0141)	Tearfulness	-0.0274^{***} (0.0096)	Czech Republic	-0.4814^{***} (0.0235)
Fracture	-0.3312^{***} (0.0279)	Cut 1	-5.1334^{***} (0.0463)	Poland	-0.9733^{***} (0.0344)
Age	-0.0275^{***} (0.0006)	Cut 2	-3.4868^{***} (0.0444)	Slovenia	-0.467^{***} (0.0306)
Male	-0.1688^{***} (0.0606)	Cut 3	-1.8771^{***} (0.0431)	Estonia	-1.0942^{***} (0.0231)
Age*Male	0.0019^{**} (0.0009)	Cut 4	-0.6280^{***} (0.0426)	Austria	Reference

+: dependent variable is self-reported health evaluated on a 5-levels scale: Excellent, Very good, .
Good, Fair, and Poor. ***: significant at 1% level, **: significant at 5% level, *: significant at 10% level.
Standard errors are in parenthesis.

Table 13: Ordered probit estimates of working conditions

Variable+	Coefficients
Job physically demanding	-0.0227 (0.0205)
Time pressure/heavy workload	-0.1184^{***} (0.0196)
Little freedom to decide how to do the work	-0.2826^{***} (0.0222)
No opportunity to develop new skills	-0.4611^{***} (0.0223)
No receive support in difficult situation	-0.4159^{***} (0.0232)
No receive recognition for the work	-0.5804^{***} (0.0237)
Salary or earnings are not adequate	-0.2938^{***} (0.0207)
Poor job security	-0.2654^{***} (0.0228)
Poor prospects for job advancement	-0.2608^{***} (0.0207)
Age	0.0238^{***} (0.002)
Male	-0.0607^{***} (0.0209)
Undergraduate or graduated studies	0.0545^{**} (0.023)
Very good health++	-0.2219^{***} (0.0293)
Good health++	-0.4179^{***} (0.0291)
Fair health++	-0.5359^{***} (0.0355)
Poor health++	-0.6466^{***} (0.0673)
Cut 1	-3.2466^{***} (0.1215)
Cut 2	-2.0563^{***} (0.1164)
Cut 3	0.3171^{***} (0.1142)

+ Dependent variable is Job satisfaction evaluated on a 4-levels scale Strongly agree, Agree, Disagree, Strongly disagree. ***: significant at 1% level, **: significant at 5% level, ++ reference in Excellent health. Standard errors are in parenthesis.

Appendix 4: Descriptive statistics on health, financial situation and early retirement in Europe

Table 14: Health stock level

Variable	Modalities	Wave 1	Wave 2	Wave 4	Wave 5	Overall
Mean of health stock		9.599 (0.9484)	9.4627 (1.0292)	9.1703 (1.098)	9.1598 (1.0868)	9.2994 (1.0717)
Job Status	Retired	9.3158 (0.0089)	9.1792 (0.0082)	8.9038 (0.0068)	8.9254 (0.0066)	9.0207 (0.0038)
	Worker	10.1707 (0.0077)	10.1225 (0.0076)	9.7998 (0.0081)	9.8232 (0.0083)	9.9481 (0.0042)
	Difference	-0.8549^{***} (0.0118)	-0.9433^{***} (0.0112)	-0.896^{***} (0.0105)	-0.8977^{***} (0.0106)	-0.9274^{***} (0.0056)
Look for early retirement	Yes	10.090 (0.0123)	9.9852 (0.0127)	9.7269 (0.0122)	9.7329 (0.0129)	9.8606 (0.0065)
	No	10.2361 (0.0098)	10.2231 (0.0092)	9.8512 (0.0108)	9.8837 (0.0108)	10.0113 (0.0055)
	Difference	-0.1461^{***} (0.0157)	-0.2378^{***} (0.0157)	-0.1243^{***} (0.0163)	-0.1508^{***} (0.0169)	-0.1507^{***} (0.0085)
Afraid health limits ability to work	Yes	9.9168 (0.0169)	9.8367 (0.0172)	9.5209 (0.0168)	9.5241 (0.0183)	9.6698 (0.009)
	No	10.273 (0.0082)	10.2315 (0.0079)	9.9169 (0.009)	9.9276 (0.0091)	10.0564 (0.0045)
	Difference	-0.3563^{***} (0.0187)	-0.3948^{***} (0.0189)	-0.396^{***} (0.0081)	-0.4035^{***} (0.0205)	-0.3866^{***} (0.0101)

*** significant at 1% level. Standard errors are in parenthesis.

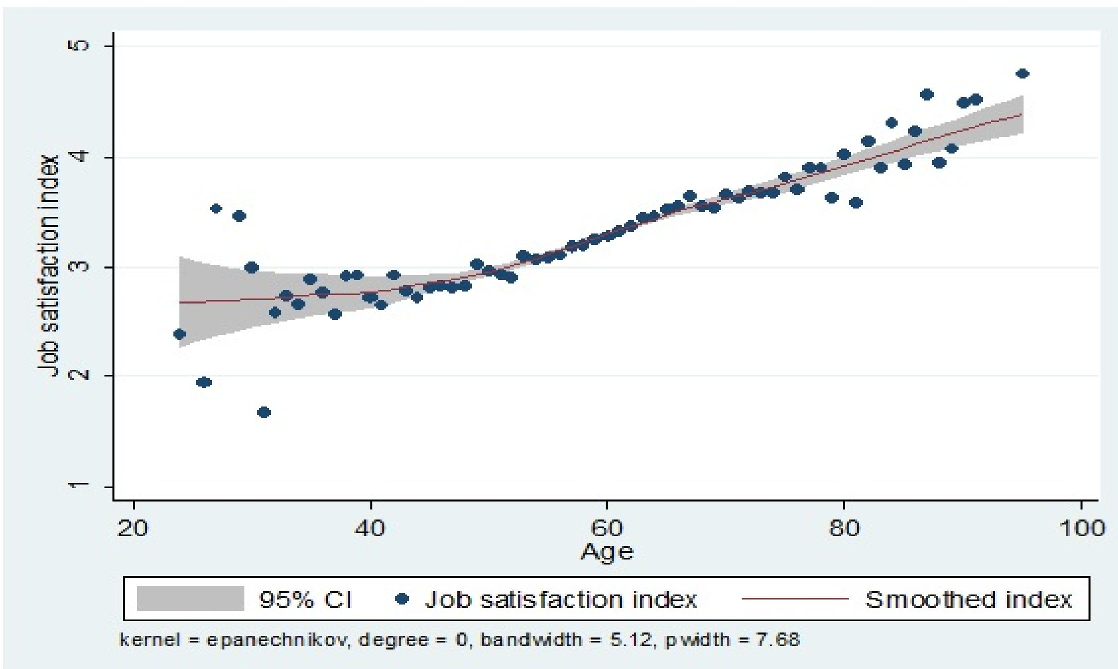

Figure 3: Evolution of job satisfaction indicator among age

Table 15: Characterization of early retirement in Europe: Part 1

Variable	Early+	Wave 1	Wave 2	Wave 4	Wave 5	Overall
Proportion of worker	in %	43.26	41.85	39, 94	38.88	40.7
looking for early retirement	Obs.	6, 840	8, 105	11, 428	9, 886	36, 259
Proportion of smoker	Yes	0.2815	0.2621	0.2397	0.1964	0.242
		(0.0083)	(0.0076)	(0.0063)	(0.0064)	(0.0035)
	No	0.2363	0.2166	0.2073	0.1802	0.207
		(0.0068)	(0.006)	(0.0049)	(0.0049)	(0.0028)
	Difference	0.0452***	0.0454***	0.0324***	0.0162**	0.035***
		(0.0106)	(0.0096)	(0.0079)	(0.008)	(0.0044)
Proportion of male	Yes	0.5465	0.5139	0.4748	0.4737	0.4979
		(0.0092)	(0.0086)	(0.0074)	(0.008)	(0.0041)
	No	0.4945	0.4963	0.4599	0.4547	0.4727
		(0.008)	(0.0073)	(0.006)	(0.0064)	(0.0034)
	Difference	0.052***	0.0176	0.0149	0.0191*	0.0252***
		(0.0122)	(0.0113)	(0.0095)	(0.0103)	(0.0053)
Proportion of worker that	Yes	0.3721	0.3721	0.3935	0.373	0.379
		(0.0089)	(0.0083)	(0.0072)	(0.0078)	(0.004)
are afraid that health limits	No	0.1927	0.1842	0.1916	0.1592	0.1811
		(0.0063)	(0.0056)	(0.0047)	(0.0047)	(0.0026)
ability to work	Difference	0.1794***	0.1879***	0.2019***	0.2138***	0.1979***
		(0.0108)	(0.0099)	(0.0085)	(0.0088)	(0.0048)
Proportion of worker	Yes	0.8364	0.8275	0.7627	0.7575	0.791
		(0.0068)	(0.0065)	(0.0063)	(0.0069)	(0.0033)
in couple	No	0.8093	0.8088	0.748	0.7458	0.7718
		(0.0063)	(0.0057)	(0.0052)	(0.0056)	(0.0029)
	Difference	0.0271***	0.0187**	0.0147*	0.0118	0.0193***
		(0.0094)	(0.0087)	(0.0082)	(0.0089)	(0.0044)
Mean of age in year	Yes	55.61	55.84	55.96	57.3	56.21
		(0.0814)	(0.0766)	(0.0664)	(0.0711)	(0.037)
	No	56.18	56.74	57.37	58.78	57.42
		(0.0861)	(0.0768)	(0.0699)	(0.0718)	(0.0383)
	Difference	−0.57***	−0.91***	−1.42***	−1.48***	−1.21***
		(0.1185)	(0.1084)	(0.0964)	(0.101)	(0.0533)
Proportion of workers that	Yes	0.8628	0.8567	0.8718	0.8574	0.6692
		(0.0063)	(0.006)	(0.0049)	(0.0155)	(0.0039)
are satisfy of their job	No	0.9531	0.9635	0.9672	0.9626	0.7292
		(0.0034)	(0.0027)	(0.0021)	(0.0066)	(0.003)
	Difference	−0.0903***	−0.1068***	−0.0954***	−0.1052	−0.0599***
		(0.0068)	(0.0061)	(0.0049)	(0.015)	(0.0049)

+: look for early retirement. Standard errors are in parenthesis. ***: significant at 1% level.
**: significant at 5% level, *: significant at 10% level

Table 16: Characterization of early retirement in Europe: Part 2

Variable	Early+	Wave 1	Wave 2	Wave 4	Wave 5	Overall
Mean of annual	Yes	$25,565.87$ (180.83)	$17,885.61$ (138.73)	$19,502.44$ (130.43)	$21,209.61$ (144.76)	$20,913.96$ (74.83)
earnings from	No	$28,305.94$ (187.18)	$20,288.7$ (136.21)	$22,479.46$ (128.97)	$24,145.13$ (139.52)	$23,628.62$ (73.79)
employment in €	Diff.	$-2,740.09^{***}$ (265.63)	$-2,403.09^{***}$ (199.28)	$-2,977.02^{***}$ (190.29)	$-2,935.52^{***}$ (208.60)	$-2,714.66^{***}$ (108.33)
Amount in bank	Yes	$12,336.73$ (198.78)	$15,486.33$ (252.69)	$17,082.53$ (303.44)	$15,111.29$ (243.92)	$15,238.72$ (133.67)
account in €	No	15253.45 (208.16)	$23,741.11$ (313.56)	$24,741.46$ (311.09)	$23,644.07$ (283.19)	$22,445.74$ (149.55)
	Diff.	$-2,916.72^{***}$ (294.52)	$-8,254.77^{***}$ (425.84)	$-7,658.93^{***}$ (453.93)	$-8,532.79^{***}$ (402.79)	$-7,207.03^{***}$ (211.12)
Out-of-pocket	Yes	293.96 (4.90)	269.03 (5.14)	-	435.79 (6.71)	344.46 (3.48)
health expenditures	No	312.22 (5.00)	279.44 (3.59)	-	463.96 (5.53)	370.91 (3.02)
in €	Diff.	-18.26^{**} (7.13)	-10.41^{*} (6.07)	-	-28.17^{***} (8.76)	-26.45^{***} (4.64)
Proportion of	Yes	0.2406 (0.0079)	0.2565 (0.0075)	0.1933 (0.0058)	0.2734 (0.0072)	0.2382 (0.0035)
undergraduate	No	0.3187 (0.0075)	0.366 (0.007)	0.2880 (0.0055)	0.3805 (0.0062)	0.3367 (0.0032)
studies at least	Diff.	-0.0781^{***} (0.011)	-0.1095^{***} (0.0105)	-0.0948^{***} (0.0083)	-0.1071^{***} (0.0098)	-0.0985^{***} (0.0049)
Percentage of	Yes	33.3586 (0.7757)	36.3031 (0.672)	41.5433 (0.5732)	43.7965 (0.6365)	39.251 (0.329)
salary to be	No	28.5844 (0.634)	29.7371 (0.5162)	33.6839 (0.4709)	37.5918 (0.4963)	32.8254 (0.2615)
received as pension	Diff.	4.7742^{***} (1.0018)	6.566^{***} (0.8474)	7.8594^{***} (0.7418)	6.2047^{***} (0.8071)	6.4256^{***} (0.4203)
Mean of job	Yes	2.7745 (0.0133)	2.6746 (0.0126)	2.6664 (0.0113)	3.6753 (0.0079)	2.9527 (0.0067)
satisfaction and	No	3.1979 (0.0105)	3.1496 (0.0092)	3.1138 (0.0082)	3.7612 (0.0051)	3.3341 (0.0046)
condition indicator	Diff.	-0.4234^{***} (0.017)	-0.475^{***} (0.0156)	-0.4474^{***} (0.0139)	-0.1406^{***} (0.0094)	-0.3814^{***} (0.0081)

+: look for early retirement. Standard errors are in parenthesis. ***: significant at 1% level.
**: significant at 5% level, *: significant at 10% level

Appendix 5: Descriptive statistics on post retirement employment

Table 17: Proportion of retired workers among aged worker per country, school grade and gender

	Wave 1			Wave 2			Wave 4			Wave 5			Overall		
Country	*Male*	*Female*	*Total*	*Male*	*Female*	*Total*	*Male*	*Female*	*Total*	*Male*	*Female*	*Total*	*Male*	*Female*	*Total*
								Per country							
Austria	0,8	6,7	3,4	0	7,3	3,4	3,3	10,3	6,9	1,6	7,8	4,8	2,1	8,8	5,5
Germany	5,3	2,6	4	3,3	1,7	2,5	8	4,4	5,9	7,4	3,6	5,2	5,4	2,9	4,1
Sweden	1,5	0,4	0,9	4	1	2,3	5,9	2,5	4,1	12,1	1,8	6,7	4,7	1,1	2,8
Netherlands	1,7	1	1,3	1,2	1,7	1,4	1,5	1	1,2	4,4	1,9	3,1	2,1	1,4	1,7
Spain	2,6	4,4	3,3	1,3	1,9	1,5	2,2	2,2	2,2	3,2	2,5	2,8	2,3	2,6	2,4
Italy	3,8	2,6	3,3	4,6	1	3	6,4	1,3	4,1	3,3	2,3	2,8	4,7	1,7	3,3
France	4,5	6,2	5,5	6,8	7,7	7,3	10,2	8,9	9,5	15,5	10,7	12,8	9,7	8,6	9,1
Denmark	3,3	2,8	3	4	1,8	2,9	6,3	2,3	4,3	8,1	3,8	5,9	5,6	2,6	4,1
Greece	3,4	0,8	2,4	6	2	4,5	–	–	–	–	–	–	4,7	1,4	3,4
Switzerland	9,1	5,6	7,4	6,9	3,7	5,3	7,7	6	6,8	10,8	7	8,8	8,8	5,9	7,3
Belgium	0,9	1,1	1	1,8	0,3	1,1	1,9	1,1	1,5	2	0,9	1,4	1,7	0,9	1,3
Israel	8,3	5,1	6,6	11,3	7	9,1	0	0	0	21,8	20,8	21,3	12,7	9,4	11,1
Czech Republic	–	–	–	4,5	3,4	4	3,4	4,9	4,2	5	4,7	4,8	4,2	4,5	4,4
Poland	–	–	–	0	2,2	1	2	4,7	3,3	–	–	–	0,8	3,1	1,9
Slovenia	–	–	–	–	–	–	0,5	0	0,3	2,9	0	1,4	1,6	0	0,8
Estonia	–	–	–	–	–	–	24,6	28,2	26,7	25,1	30,6	28,4	24,8	29,3	27,5
Total	3,6	2,9	3,2	4,4	2,9	3,7	7,8	8,6	8,2	10,2	10	10,1	6,8	6,8	6,8

Table 18: Proportion of retired workers among aged worker per country and school grade

	Wave 1			Wave 2			Wave 4			Wave 5			Overall		
Country	*Male*	*Female*	*Total*	*Male*	*Female*	*Total*	*Male*	*Female*	*Total*	*Male*	*Female*	*Total*	*Male*	*Female*	*Total*
Per school grade															
no grade	7,1	5,8	6,3	12,5	3,3	6,5	–	–	–	3,8	12,8	9,2	8	6,5	7,1
college degree	2,6	2,9	2,7	4	3,4	3,7	8	8,2	8,1	7,9	8,9	8,4	5,8	6,3	6
undergraduate studies	6,5	4	5,2	3,8	2,4	3,1	6,4	9,1	7,9	14,2	18,1	16,4	7,3	9,6	8,6
graduate studies	3,5	1,7	2,6	5,1	2,2	3,6	9	8,7	8,8	13,6	10,2	11,7	8,3	6,4	7,3
Total	3,1	2,6	2,8	4,4	2,9	3,7	7,8	8,6	8,2	10,2	10	10,1	6,7	6,8	6,8

Appendix 6: Multiple imputation model for pension rate

Table 19: Outputs of multiple imputation model

Variable	Coefficient
Log of wage	-0.00056^{***} (0.00009)
Grade	Ref = Graduate studies
No grade	0.02295^{***} (0.00151)
College degree	0.022^{***} (0.00113)
Undergraduate studies	0.01702^{***} (0.00125)
Intercept	0.55217^{***} (0.00422)
Country	ref: Estonia
Austria	0.13666^{***} (0.00502)
Germany	0.03179^{***} (0.00542)
Sweden	-0.00509 (0.00498)
Netherlands	-0.02272^{***} (0.00534)
Spain	0.26443^{***} (0.00631)
Italy	0.15523^{***} (0.00557)
France	0.0625^{***} (0.00476)
Denmark	-0.25459^{***} (0.00478)
Greece	0.11541^{***} (0.0072)
Switzerland	-0.15168^{***} (0.00482)
Belgium	0.06925^{***} (0.00482)
Israel	-0.26053^{***} (0.00625)
Czech Republic	-0.02318^{***} (0.00507)
Slovenia	0.08582^{***} (0.00667)
Poland	0.13705^{***} (0.00732)
$\sigma_\mu = 0.17921$, $\sigma_e = 0.08981$, $\rho = 0.79929$	

***: significant at 1% level, **: significant at 5% level, Standard errors are in parenthesis.