Mean survival times and retirement ages

Linden, Mikael and Väänänen, Niko

December 2023

Mean survival times and retirement ages

Mikael Linden*[1] & Niko Väänänen **)

DECEMBER 2023

Abstract

We propose an elementary economic model which assumes that the integral of life survival function can be interpreted as a utility function. The model helps us to understand connections between individual's survival estimate to some specific age and the timing of retirement. The difference between survival and related longevity costs is maximized with an estimate of survival time. The results are derived with the concept of restricted mean survival times (*RMST*). This is also applied to the observed retirement and death ages for the Finnish year 1947 birth cohort. We show that actual survival times, i.e., mean lifetimes to the age of 73 years, which is the highest age in our follow-up sample, differ among retired and not yet retired persons between the ages from 60 to 68 years. The main result is that persons who retire in ages from 62 to 66 years have shorter mean lifetimes to the age of 73 years compared to individuals who do not retire in these ages. This is interpreted as evidence of too optimistic survival estimates among the persons retiring at the most popular retirement ages.

JEL classification: C41, J14, I12.
Keywords. retirement ages, subjective survival times, age of death, survival analysis, restricted mean survival times (RMST).

*) Corresponding author. E-mail: mika.linden@uef.fi
University of Eastern Finland/Dept. of Social and Health Management/ Health Economics
**) ETK (Finnish Centre for Pensions). E-mail: niko.vaananen@etk.fi

[1] Acknowledgements: Corresponding author acknowledges the financial support from project SustAgeable 2021-2024 (SA-15281, Academy of Finland).

1. Introduction

It is well-known that retirement timing decision is a complex process where pre- and post-retirement factors play important and often contrasting roles. In economics, timing of retirement is typically modelled with the life-cycle approach where labour supply, income and pension levels, health, and wealth, are the main driving variables in retirement decisions (see e.g. Blundell et al. 2016, Laitner and Sonnega 2012, Blake 2006, for partial literature reviews). The choice for the exact time of retirement or retirement age is quite seldom explicitly solved in this literature that gives different comparative static results with respect to retirement age. However, when the "optimal" time of retirement is in the focus, the issues of longevity risk and death hazard cannot be avoided. Here the literature refers often to the papers on economic growth and lifetime consumption where changes in mortality, population age profile, and health, have effects on growth and consumption, or to the papers on insurance plans where stochastic death processes with annuities have a major role (see e.g. Kalemli-Ozcan and Weil (2010), Mao et al. (2014), d'Albis et al. (2012), Chen et al. (2021a and 2021b)). As the level of model complexity is high in these papers, only a few econometric results are found (see Hazan (2009), Bloom et al. (2014)). Contrary to above there exists a large empirical public health and health economics literature on the relationship between retirement and mortality. Main result here is the ambiguous effect of retirement on mortality after controlling for health (see, e.g., Sewdas et al. (2020), Brockmann et al. (2009), Hernaes et al. (2013), Hallberg et al. (2015), Bloemen et al. (2017)).

Many countries have flexible retirement ages, an age window that permits the retiree to choose and delay his/her "optimal" retirement age. In a scheme in which the individual can choose freely the retirement age, after a certain threshold, the importance of expected survival age is evident when we observe that, in *ex-post* sense, the following elementary relation is valid

$$RET_i = \chi^*_{T,i} - T_{R,i} \geq 0,$$

where RET_i is the *observed* retirement spell or duration, $\chi^*_{T,i}$ is the age of death, and $T_{R,i}$ is the chosen retirement age. However at the age of $T_{R,I}$, and before it, the age of death is a random variable $\chi^*_{T,i}$, and the retiree has some conjectures over it, such as $\chi_{T,i}$. Typically, $\chi_{T,i}$ is the individual's *subjective* estimate of his/her survival to some specific age, and this can differ greatly from his/her remaining actual lifetime (measured in years).

This means that an individual's *ex-ante* calculation of retirement spell $RET_i = \chi_{T,i} - T_{R,i}$ is a demanding task as the valuation mistakes and systematic forecast biases on $\chi^*_{T,i}$ can be large. We could argue, irrespectively of the quality of estimate $\chi_{T,i}$, that if subjective survival age estimates are important for the retirees, then we should write the above equation in the form of *intended* or *planned* retirement spell $RET_i^I(\chi_{T,i}) = \chi_{T,i} - T_{R,i}(\chi_{T,i})$ where the retirement age is also a function of the estimate of remaining life time (for more details, see Linden (2022)).

Our above approach to retirement is supported by the large new literature on subjective survival probabilities and longevity expectations. The literature shows that people can predict, on average, quite well their actual survival rates and remaining lifetimes. Results with the US data show that men overestimate, and females underestimate their survival probabilities compared to *life table* survival probabilities, but males predict their life expectancy better than females (Hamermesh (1985), Hurd and McGarry (1995), Perozek (2008), Post and Hanewald (2013)). However, Teppa (2011) shows with Dutch data that both males and females have lower subjective survival probabilities relative to life table ones. Palloni and Novak (2016), using more recent data from Austria, find that the subjective probabilities are remarkably close to the results of actual life tables. More heterogeneous results are obtained when survival expectations to different ages are analysed. Wu et al. (2015) show with Australian survey data that, after averaging out idiosyncratic differences, individual subjective survival curves do not match the shape of population survival curves. People underestimate their chance of surviving to nearby ages and overestimate their chance to survive to much older ages. On average, people also underestimate their overall life expectancy, women more than men, and younger more than older. However, the result that older respondents report overly optimistic subjective survival probabilities has been often documented in the literature with different data sets (see, e.g., Elder (2013), Hudomiet and Willis (2013), O'Dea and Sturrock (2019)).

In sum, the results above show that subjective estimates contain information on the actual survival rates. As life expectancy plays an important role in the life cycle models of economic behaviour like labour supply, savings, and retirement (see e.g. Wolfe (1983), Chang (1991), Bloom et al. (2004), Sheshinski (2006), Kalemli-Ozcan and Weil (2010)), some empirical papers have linked subjective survival estimates to retirement decisions. The results so far are quite mixed. Hurd et al. (2004) report that those with particularly low expectations of survival to age of 85 are more likely to retire earlier. Delavande et al. (2006) focus on subjective survival to age of 75 and use parents' longevity as instrument to deal with measurement error. They find no impact of subjective survival on the retirement probability over the subsequent two years for those who were not retired at the age of 62 years. However, O'Donnell et al. (2008) show with UK data that individuals that are extremely pessimistic about their chances of survival are least likely to retire. O'Donnell et al. suggests also that the direction of subjective survival effect on timing of retirement is ambiguous, and it is possibly non-linear. They find in UK data a significant concave relationship between mortality expectations and retirement. As expectations improve from low base, the retirement probability first rises, albeit it falls thereafter. When controlling for health, there is still a substantial and significant effect of survival expectations on retirement age.

Next, we propose a quite elementary economic model to understand connections between survival time expectations and timing of retirement. After that we analyse actual retirement ages, retirement durations, and ages of death for the 1947 Finnish birth cohort. We show with survival data methods that actual survival estimates differ among retired and not yet retired at different ages between ages of 60 and 68 years. The main result is that individuals who retire before ages from 62 to 66 years have shorter mean lifetimes to age of 73 years compared to persons who do not retire at these ages. We interpret this as an evidence of too optimistic subjective longevity expectations that the retired persons have, especially retiring close to the age of 63 years.

2. Model of survival to pre-determined date

Let T to be a random variable expressing survival time to some age. Let $t_0 = \chi_{T,i}$ be retiree's own subjective estimate of his/her survival age. The *restricted mean survival time* (*RMST*) $E[\min\{T, t_0\}]$ is the expected value of the minimum of T and t_0 over the considered period. Aging equally results in increasing (relative) costs to individual as he/she gets older, i.e., costs in relation to fixed pension income $C(t)/\bar{Y} = c(t)$ is increasing with age $c'(t_0) > 0$. Here we mean by costs all the dis-utilities, functional problems, and time and health costs which getting older will cause to a person.

In more precise terms, when $t = 0$ refers to the starting time of retirement spell and $S(t_0)$ is the subjective survival function corresponding to cumulative density function of $F(t_0)$, i.e.,

$S(t_0) = 1 - F(t_0) = 1 - Prob\{t \le t_0)$, the retiree faces the following maximization problem for his/her life value function with respect to survival age estimate *t0* (for more details, see Appendix 1):

$$\underset{\{t_0\}}{Max}\{V(t_0) = E[\min\{T, t_0\}] - \int_0^{t_0} c(u)du$$
$$= \int_0^{t_0} S(v)dv - \int_0^{t_0} c(u)du\}.$$

Conditions for the maximum are (for details, see Appendix 2):

$$\frac{dV(t_0)}{dt_0}\Big|_{t_0=t_0^*} = S(t_0) - c(t_0) = 0, \quad \text{and}$$

$$\frac{dV^2(t_0)}{dt_0^2}\Big|_{t_0=t_0^*} = S'(t_0) - c'(t_0) < 0.$$

Note that we can give a utility function interpretation to the survival *integral* function $\int_0^{t_0} S(v)dv > 0$ as it has similar properties to the standard utility function: $S(v) > 0$ and $S'(v) < 0$. Now, $\int_0^{t_0} S(v)dv - \int_0^{t_0} c(u)du$ is the estimate of "net utility mass" or "consumer's surplus" of surviving to estimated age of *t0* [2)].

In economic terms, the optimum condition says that the retiree extends his/her subjective estimate of survival age to t_0^* where the subjective survival probability $S(t_0^*)$ equals the value of relative life costs at that age. Thus, if person's life cost function is steep or shifts upward, he/she is quite pessimistic about the length and quality of his/her life's last years. This means that the "net utility" shrinks and lower level of *t0* gives the maximum net utility. Note that the model solves the optimal subjective estimate of *remaining lifetime*, not the subjective survival probability to some age. Although the model is simple and intuitive, we admit that its information requirements are quite demanding as it assumes that the retiree has a well-behaved subjective survival function specified for his/her remaining lifetime. The model intention is to show that subjective estimate of remaining lifetime can also be formulated in economic terms that corresponds to statistical approach of *RMST* analysis conducted below.

---

2) For example, function like $\int_0^{t_0} (\frac{A}{v+1})dv - \int_0^{t_0} Bu^2 du = Aln(t_0 + 1) - \frac{B}{3} t_0^3$ with suitable values for A and B can be considered here.

3. Data, institutional setting, and sample design

3.1. Data and institutional setting

We use person level register data based on year 1947 birth cohort in Finland. We focus on those who started their old age pension period as their first and only form of retirement during the follow-up time of 1.1.2007 - 31.12.2019. The sample size is 35,879 persons. Appendix 3 gives the summary statistics of data variables. Figure 1. gives the histogram of retirement ages in our sample.

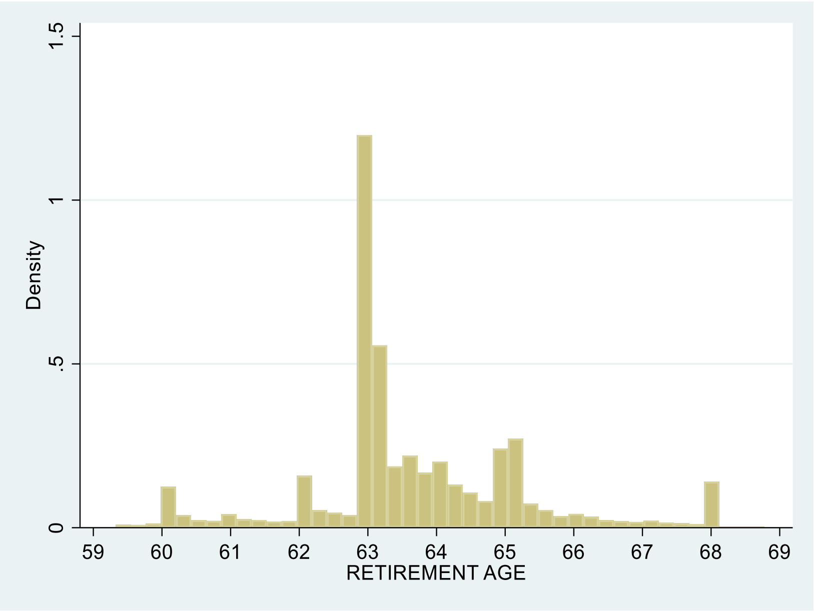

Figure 1. Histogram of retirement ages of old age pension takers (cohort 1947)

It reveals some interesting facts. In Figure 1. retirement age of 63 years is the most popular age between ages of 59 and 68 years for the year 1947 birth cohort. Another significant peak is at the age of 65. At this age the national pension which tops up the lowest public pension benefits can be taken without any reductions. Equally, some workers in the public sector had this age as their full retirement age.

The spike up in Figure 1. at the age of 63 years relates to the earliest possible retirement age. However there existed some exceptions to this rule. In Finland for cohort 1947, every individual could choose freely when to retire between the age of 63 to 68. The mandatory public pension insurance and work contract end at the age of 68. Although an individual could continue working after this age, it accrued no pension and a new contract with the employer was needed. There were no other criteria (e.g., career length or accrued pension) than fulfilling the age to take up the pension and retire. However, early retirement at the age of 62 was possible with a reduction. The pension benefit was reduced by 0,6 % for each month the pension was taken up before the age of 63. Some specific occupational groups, notably those in the public sector, including firemen, military and cost-guard officers, policemen, and some other workers, as well as sailors and farmers in the private sector, and people having individual pension contracts (e.g., golden handshakes) had special retirement ages that were lower than 63 years.

3.2. Restricted mean survival time (RMST) analysis with retirement ages

In survival time statistics *RMST* is $\mu(t_0)$, the expected value of the minimum of survival times T and pre-determined time t_0 over the follow-up period. In more precise terms we have (see Appendix 1)

$$\mu(t_0) = E[\min\{T, t_0\}] = E[T; T \le t_0] + t_0 Prob[T > t_0] = \int_0^{t_0} S(v)dv \, .$$

Thus, *RMST* is the area under the estimated survivor function to t_0 and can be interpreted as actual life expectancy in sample over a defined period of time t_0. For example, if t_0 refers to some period or age after retirement (e.g., $t_0 = 5$ years), then $\mu(t_0)$ is the *average* number of years survived (or life expectancy) over a 5-year period after retirement. This can easily be compared with life expectancy of an individual with same age but who is *not yet* retired when analysing the effects of retirement on longevity.

3.3. Sample design

This retirement age comparison with $\mu(t_0)$ makes the study design somewhat complex with the sample data. In principle we can have 7 different cases of interest here. The following Figure 2. describes the cases. In the figure 59y and 73y refer to the starting and ending ages of the follow-up in our sample. With age 63y, i.e., the earliest possible retirement age without exceptions, cases A1, A2, and A3 are the main interest of our *RMST* analysis compared to other cases. In all A1 – A3 cases the retirement happens before 63y, and person is either still alive at 73y, or dies before 63y after retiring, or dies between ages 63y and 73y. In all these cases we have observations for retirement ages and spells in our sample.

The identification of "control group" *not* retiring before 63y is a more demanding task. B1 includes all those persons that have died before the retirement age 63y, i.e., we don't know their retirement status. They do not belong to our data sample as it consists *only* of persons having retirement status after the age of 59y. The case B2 persons are neither included in our data as they also do not have retirement status. Thus, the main data problem here is the fact that

Figure 2. Retirement age (●), age of death (**x**), and age at the end of the follow-up time

some persons die before they retire – they never reach their planned retirement age – and they do not have retirement age or spell in our sample. C1 and C2 cases are the persons who retire – but not before 63y – and they either die after 63y or are still alive at the end of sample follow-up time. Thus, their retirement ages and spells are observed. Note that similar case selections are valid for the (retirement) age of 65 years (65y in Figure 2.) and, also for any other age in the sample.

All this means that our "treatment group" consist of cases A1 – A3 and "control group" consists of C1 – C2 cases. Unfortunately, we still face one data challenge as in the control group all cases retire after 63y and they cannot die before this age. This means that cut-off age of 63y operates here as a selection rule that builds-up two sample partitions that are not fully comparable. Treatment group includes survival times between ages of 59y and 73y, but control group has survival times only between 63y and 73y. Because our sample consists of aging persons, this sample partition problem will affect the survival comparison between the groups. The comparison needs to be done with persons with same age and who are still alive. The solution to this problem is to exclude from the analysis A2 cases – note the compatibility to the B2 cases – and use survival data only *after* age of 63y. [3)]

[3)] A practical way to identify an individual's retirement status, say at age of 63y, in our sample is to calculate an auxiliary variable *ret_63* by subtracting from observed retirement age (T_R) 63 years, i.e. $ret\_63 = T_R - 63$. This provides both negative and positive numbers that correspond to retirement ages that are either less or more than age of 63y. By indexing these two categories with 1 and 0 we classify persons according to their retirement status at age 63: $ret\_63\_i = (1, 0)$ = (retired, not retired).

Next, we estimate first the survival functions by retirement status at different ages. After that, we conduct restricted mean survival analysis (*RMST*) to estimate how retirement status affects the relationship between the retirement age and the mean longevity during the follow-up period.

4. Results

4.1. KM- survival estimates

Estimates of Kaplan-Meier survival functions for retirement statuses with retirement ages before and after ages of 61, 63, 65 and 68 years are depicted in Figure 3. The results give us some evidence how different retirement ages condition survival probabilities to the age of 73 years. Figure shows that retiring *before* the ages of 61 and 68 years leads to higher survival

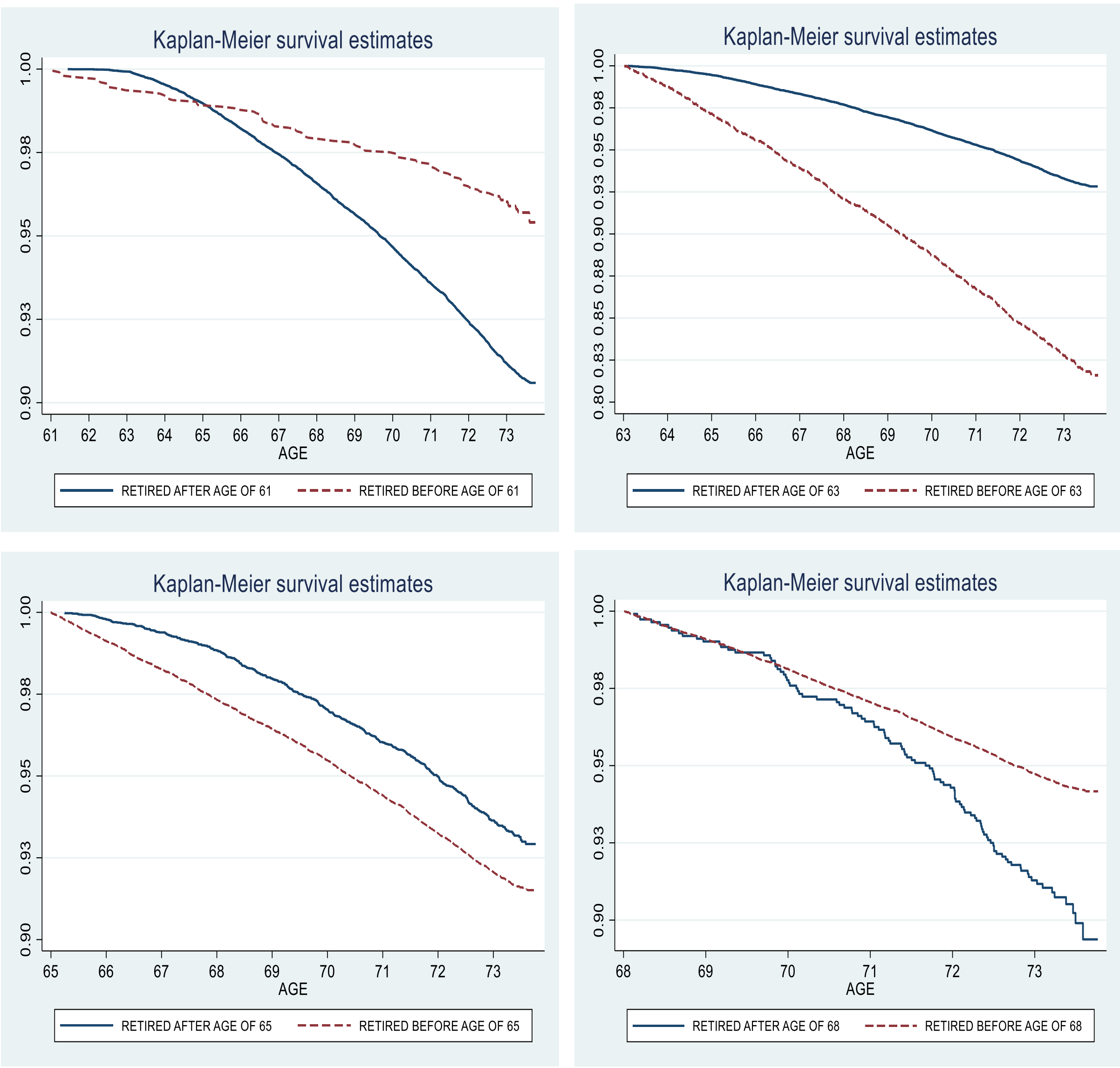

Figure 3. Kaplan-Meier survival estimates with retiring and not-retiring before ages of 61, 63, 65, and 68 years.

probabilities than retiring *after* these ages. The case is the opposite for retiring before 63 and 65 years: retirement before these ages means lower survival probabilities compared to those who retire after these ages. The evident heterogeneity in these results indicates that the retirement at different ages corresponds to different survival profiles. This is next analysed with the *RMST* methods in details.

4.2. RMST estimates

RMST analysis is conducted with retirement ages below 60 years, next with ages below 60 years and 3 months, and so on, and finally with age below 68 years, as cut-off ages.[4)] We keep the upper age of *RMST* integral fixed to the end of our sample follow-up time age 73 of years and adjust the lower point of survival age integral to the above cut-off retirement ages, i.e., $\int_{T_R}^{73} S(v)dv.$ Thus, we calculate the mean survival ages to age of 73 years with different retirement ages and compare if the mean survival ages are different between the retired and non-retired.

Figure 4. gives the differences between *RMST* estimates added with 95% *CI'*s for those who retired or did not retire at these specific cut-off ages starting with age less of 60 years and ending with age less of 68 years. Results show that retiring between the ages of 60 and 62 gives 2 months longer expected life length up to 73 years than retiring after at those ages. Contrary to this, retiring before the age of 62 years plus 3 months to 66 years, the expected life length to 73 years is shorter than for the non-retired. The largest loss is 6 months at age of 63 years. Finally, retiring before the age of 66 years plus 3 months to 68 years gives somewhat longer life expectancy to age of 73 years than retiring after these ages.[5)]

[4)] Note that we don't use here "between approach", e.g., analysing individuals who retire (and not retire) *between* ages of 63y and 63.25y, because this gives sample truncation specific results that are less general (see also footnote 4).

[5)] In Appendix 4. we conduct related analysis between different ages and corresponding mean ages of death. Results show that there exists a dip in the mean age of deaths for persons who retire between ages of 60.5 and 63 years compared to other retirement ages.

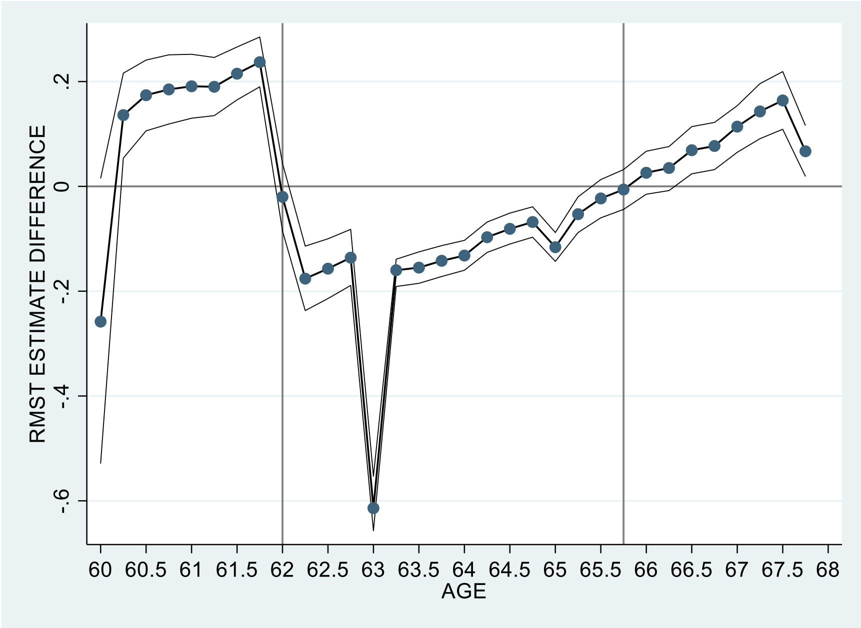

Figure 4. The difference between *RMST* values (mean lifetimes to age of 73 years) for retired and non-retired with cut-off retirement ages of 60 – 68 years.

Particularly the results indicate that individuals retiring between ages of 62 years plus 3 months to 66 years must have somewhat erroneous survival age expectations as their expected longevity to age of 73 years is less compared to individuals that have delayed their retirement in these ages. Result is understandable in this context as many other things affect the decision to retire. One explanation was given in Section 2. If an individual's age life cost function, e.g., due illness, is steep or shifts upward differently at some specific retirement age this shortens the optimal subjective survival time estimate and we expect that retirement time is advanced *if* planned retirement duration is kept unchanged. Appendix 5 gives some preliminary results how one illness related variable modifies the above results. We conclude that large number of retirees choose earliest or close to earliest possible retirement age despite the lower actual expected life length involved with these ages compared to individuals who do not retire at these ages.

5. Conclusions

The paper introduced the concept of restricted mean survival times (*RMST*) into the analysis of expected life lengths and retirement timing. We showed that *RMST* has also a natural interpretation in terms of utility function. Optimal estimate of subjective survival times was derived by maximizing the difference between cumulative survival function and corresponding life cost function. Next *RMST* approach was applied to actual retirement and death ages for the Finnish year 1947 birth cohort. We showed that actual survival time estimates differ among the retired and not yet retired with different ages below the ages of 60 to 68 years. The main result is that persons who retire in ages from 62 to 66 years have shorter mean lifetimes to the age of 73 years compared to individuals who do not retire in these ages. Especially, close to the age of 63 years, the loss in mean survival times is largest. This is interpreted as an evidence of too optimistic subjective life expectancies among persons retiring between the ages of 62 and 66 years. The results are novel, and we have shown that *RMST* approach is a valuable tool in this context both in theory and in empirics.

Future results will show if the obtained heterogenous mean lifetime results are still valid when we control for full set of covariates that are relevant in this context, i.e., health, incomes, wealth, and pensions. The role of institutions, norms, and framing effects of pension system in retirement decisions must be analysed in detail. Also, a closer look on the relevance of subjective survival times on intended and actual retirement ages must be conducted. Data on proper measurements on the subjective survival time estimates and intended retirement ages are important here.

Appendix 1. Restricted mean survival time

The ***restricted mean survival time*** (*RMST*) is the expected value of the minimum of random survival time T and pre-determined time t_0 over the follow-up period. In more precise terms we have

$$\mu(t_0) = E[\min\{T, t_0\}] = E[T; T \le t_0] + t_0 Prob[T > t_0].$$

Now

$$E[T; T \le t_0] = \int_0^{t_0} vf(v) = vF(v)|_0^{t_0} - \int_0^{t_0} F(v)dv = t_0 F(t_0) - \int_0^{t_0} F(v)dv\ .$$

Expressing this in terms of survival function $S(t) = 1 - F(t)$ gives

$$E[T; T \le t_0] = t_0(1 - S(t_0)) - \int_0^{t_0} (1 - S(v))dv = \int_0^{t_0} S(v)dv - t_0 S(t_0).$$

Finally, *RMST* is

$$\mu(t_0) = E[\min\{T, t_0\}] = E[T; T \le t_0] + t_0 Prob[T > t_0]$$

$$= \int_0^{t_0} S(v)dv - t_0 S(t_0) + t_0 S(t_0) = \int_0^{t_0} S(v)dv.$$

Thus, *RMST* is the area under the estimated survivor function to t_0 and can be interpreted as actual life expectancy in sample over a defined period of t_0. This is usually taken to be close the longest observed event time in the data (see Collett 2015, pp. 389-390).

Appendix 2. 2nd order conditions for

$$\underset{\{t_0\}}{Max} V(t_0)\{\int_0^{t_0} S(v)dv - \int_0^{t_0} c(u)du\}.$$

Now conditions for maximum are

$$\frac{dV(t_0)}{dt_0}|_{t_0=t_0^*} = S(t_0) - c(t_0) = 0 \Leftrightarrow 1 - F(t_0) = c(t_0) = 0,$$

$$\frac{d^2V(t_0)}{dt_0^2}|_{t_0=t_0^*} = \frac{d}{dt_0}[1 - F(t_0)] - \frac{d}{dt_0}c(t_0) = S'(t_0) - c'(t_0) < 0.$$

Last result is based on the properties of survival function.

Appendix 3. Data sources and variable summary statistics

Data sources
Person level register follow-up data starting 1.1.2007 and ending 31.12.2019.
Statistics of Finland: birthday in year 1947, date of death.
ETK (Finnish Centre for Pensions): date of retirement.
KELA (The Social Insurance Institution of Finland): number of days of sickness leave.

Summary statistics
Old age retirement age (T_R): calculated in days and converted to years (# of days/365.26)

Summary statistics for variable T_R by categories of DEAD = 0/1(NO/YES)

DEAD	mean	median	min	max	se(mean)	sd	cv	N
0	63.670	63.160	59.106	72.376	0.009	1.624	0.026	32714
1	63.612	63.046	59.243	71.612	0.029	1.605	0.025	3165
Total	63.665	63.139	59.106	72.376	0.009	1.622	0.025	35879

Age (AGE): calculated in days and converted to years (# of days/365.26)

Summary statistics for variable AGE by categories of DEAD = 0/1(NO/YES)

DEAD	mean	median	min	max	se(mean)	sd	cv	N
0	73.277	73.285	72.770	73.767	0.002	0.286	0.004	32714
1	68.855	69.195	59.716	73.616	0.051	2.888	0.042	3165
Total	72.887	73.236	59.716	73.767	0.008	1.543	0.021	35879

Appendix 4. Retirement ages and average ages of death

Different analysis, but related to above *RMST* -analysis, can be conducted among the *dead* persons who have retired at some specific age. We conduct the analysis in the same retirement age classes as in the main *RMST* –analysis. Figure A4-1 below depicts the *mean ages of death* for persons who retire before and after specific ages.

The higher line is the mean ages (added with 95% CI's) of those who retire *after* specific retirement age and the lower line is the mean age of death for those who retire *before* the same specific age. The results are interesting and comparable with the *RMST* –analysis results. When retiring between ages of 62-63 years with before status there exists a dip down in the mean age of death compared to persons who retire after these years.

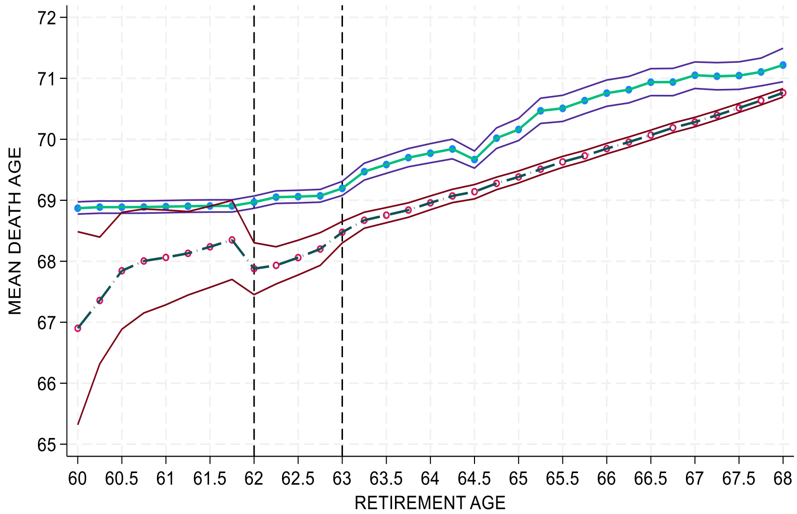

Figure A4-1 Mean ages of death and retirement ages (retirement after specific age: --●--, retirement before specific age: --○--).

Figure A4-2 (below) gives the *mean age of deaths with-in* the specific ages. We observe that the mean age of death line increases quite rapidly when retirement age is less than 60.5 years. After this it has a major dip down, and the higher level is restored back at retirement age of 64 years. After this mean age of deaths is less than retirement age + 5 years indicating that the mean lengths of retirement spells *among the dead retirees* shorten quite fast - as expected - when the retirement age increases.

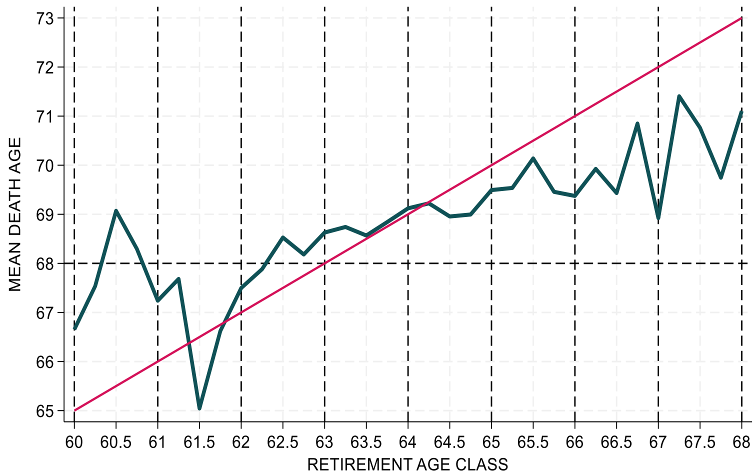

Figure A4-2 Mean age of deaths in retirement age classes 59 – 60, 60 – 60.25, ..., 67.75–68

Both these figures help us to understand presented *RMST* –analysis results that pay attention to the survival aspects (i.e., life expectancy) between retirement ages and observed ages at the end of sample follow-up, i.e., persons still alive after retirement have also a role in the analysis.

Appendix 5. *RMST* results for retirement before of 63 years with the number of days of sickness allowance.

Our data contained only one variable related to person's health. It was the number of days for sickness allowance paid to a person before old age retirement. The variable is closely related to person's health status. Sickness allowance and leave are accepted after pedantic medical consultation. We classify the variable into five categories depending on the number of sickness leave days in the following way.

NUMBER OF DAYS	Freq.	Percent	Cum.
none:	22,049	61.53	61.53
1-29:	10,690	29.83	91.36
30-89:	1,600	4.47	95.83
90-179:	799	2.23	98.06
over 179:	696	1.94	100.00
Total	35,834		

RMST between-group contrast between retired and non-retired at age of 63 years

NUMBER OF DAYS	RMST Contrast Estimate	[95% Conf.	Interval]	P>|z|
none	-0.549	-0.620	-0.478	0.000
1-29	-0.600	-0.705	-0.496	0.000
30-89	-0.558	-0.892	-0.224	0.001
90-179	-1.531	-2.288	-0.775	0.000
over 179	-2.942	-3.952	-1.933	0.000

The second table gives the RMST results in different sickness leave categories. When the sickness leave lasts less than 3 months it has no classifying effect on the difference of mean survival times between retired and non-retired at age of 63. The estimate values are at same level as in Figure 4. above at age of 63 years. However, when the leave length is longer than 3 or 6 months *RMST* contrast estimate increases (in absolute terms) noticeable. This indicates that lengthen sickness shortens radically the mean survival time to age of 73 years among the persons who retired before the age of 63 compared to ones who did not retire before this age.

References

d'Albis, H., S.-H.P Lau, and M. Sánchez-Romero (2012).”Mortality transition and differential incentives for early retirement.” Journal of Economic Theory 147, 261–283

Blake, D. (2006). *Pension Economics*. New York: Wiley.

Bloemen, H., S. Hochguertel, and J. Zweerink (2017). “The causal effect of retirement on mortality: Evidence from targeted incentives to retire early.” Health Economics 26, 204–218.

Bloom, D.E., D. Canning, and M. Moore (2014). “Optimal retirement with increasing longevity.” Scandinavian Journal of Economics 166, 838–858.

Bloom, D.E., D. Canning, M. Moore, and Y. (2006). "The effect of subjective survival probabilities on retirement and wealth in the United States." In *Population Aging, Intergenerational Transfers and the Macroeconomy*. 67–99. Eds. R. Clark, N. Ogawa, and A. Mason. Cheltenham: Edward Elgar Publishing.

Bloom, D.E., D. Canning, and M. Moore (2004). *The Effect of improvements in health and longevity on optimal retirement saving.* NBER Working Paper 10919.

Blundell, R., E. French, and G. Tetlow (2016). "Retirement incentives and labour supply." In *Handbook of the Economics of Population Aging*. 457-566. Eds. J. Piggott and A. Woodland. Amsterdam: North-Holland.

Brockmann, H., R. Muller, and U. Helmert (2009). "Time to retire – time to die? A prospective cohort study of the effects of early retirement on long-term survival." Social Science & Medicine 69, 160–164

Chang, F.-R. (1991). "Uncertain lifetimes, retirement and economic welfare." Economica 58, 215–232.

Chen, A., M,. Hentschel, and M. Steffensen (2021a). "On retirement time decision making." Insurance: Mathematics and Economics 100, 107–129

Chen, A., P. Hieber, and M. Rach, (2021b). "Optimal retirement products under subjective mortality beliefs." Insurance: Mathematics and Economics 101, 55–69.

Collett, D. (2015). *Modelling Survival Data in Medical Research.* 3rd edition. Boca Raton: CRC Press.

Delavande, A., and S. Rohwedder (2011). "Differential survival in Europe and the United States: Estimates based on subjective probabilities of survival." Demography 48, 1377–1400.

Elder, T. E. (2013). "The predictive validity of subjective mortality expectations: Evidence from the health and retirement study." Demography 50, 569-589.

Hallberg, D., P. Johansson, P., and M. Josephson (2015). "Is an early retirement offer good for your health? Quasi-experimental evidence from the army." Journal of Health Economics 44, 274–285.

Hamermesh, D. S. (1985). "Expectations, life expectancy, and economic behaviour." Quarterly Journal of Economics 100, 389-408.

Hazan, M. (2009). "Longevity and lifetime labour supply: Evidence and implications." Econometrica 77, 1829–1863

Hernaes, E., S. Markussen, J. Piggott, and O.L. Vestad (2013). "Does retirement age impact mortality?" Journal of Health Economics 32, 586–598

Hudomiet, P., and R.J. Willis (2013). "Estimating second order probability beliefs from subjective survival data." Decision Analysis 10, 152–170.

Hurd, M.D., and K. McGarry (1995). "Evaluating subjective probabilities of survival in the health and retirement study." Journal of Human Resources 30 (Supplement), S268-S292.

Hurd, M. D., J.P. Smith, and J.M. Zissimopoulos (2004). "The effects of subjective survival on retirement and Social Security claiming." Journal of Applied Econometrics 19, 761–775.

Kalemli-Ozcan, S., and D. Weil (2010). "Mortality change, the uncertainty effect, and retirement." Journal of Economic Growth 15, 65-91.
Laitner, J., and A. Sonnega, (2012). "Economic Theories of Retirement." In *The Oxford Handbook of Retirement* (e-book). Ed. M. Wang. Oxford: OUP.

Linden, M. (2022). *Retirement duration maximization with survival time expectations*. MPRA Paper No. 115903/December 2022.

Mao, H., K.M. Ostaszewski, and Y. Wang (2014). "Optimal retirement age, leisure and consumption." Economic Modelling 43, 458–464

O'Dea, C., and S. Sturrock (2019). *Survival pessimism and the demand for annuities.* IFS Working Paper W19/02.

O'Donnell, O., F. Teppa, and E. van Doorslaer (2008). *Can subjective survival expectations explain retirement behaviour?* DNB Working Paper, No. 188.

Palloni, A., and B. Novak (2016). "Subjective survival expectations and observed survival: How consistent are they?" Vienna Yearbook of Population Research 14, 187–227

Perozek, M. (2008). "Using subjective expectations to forecast longevity: Do survey respondents know something we don't know?" Demography 45, 95–113.

Post, T., and K. Hanewald (2013). "Longevity risk, subjective survival expectations, and individual saving behaviour." Journal of Economic Behavior & Organization 86, 200– 220.

Sewdas, R., A. de Wind, S. Stenholm, P. Coenen, I. Louwerse, C. Boot, and A. van der Beek (2020). "Association between retirement and mortality: working longer, living longer? A systematic review and meta-analysis." Journal of Epidemiology and Community Health 74, 473–480.

Sheshinski, E. (2006). "Note on longevity and aggregate savings." Scandinavian Journal of Economics 108, 353-356.

Teppa, F. (2011). *Can the Longevity Risk alleviate the annuitization puzzle? Empirical evidence from Dutch data*. DNB Working Paper, No. 302.

Wolfe, J. R. (1983). "Perceived longevity and early retirement." The Review of Economics and Statistics 65, 544–551.

Wu, S., R. Stevens, S.Thorp (2015). «Cohort and target age effects on subjective survival probabilities: Implications for models of the retirement phase." Journal of Economic Dynamics and Control 55, 39–56.