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Individual Uncertainty About Longevity

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Abstract This article presents an assessment of individual uncertainty about longevity. A survey performed on 3,331 French people enables us to record several survival probabilities per individual. On this basis, we compute subjective life expectancies (SLE) and subjective uncertainty regarding longevity (SUL), the standard deviation of each individual's subjective distribution of her or his own longevity. It is large and equal to more than 10 years for men and women. Its magnitude is comparable to the variability of longevity observed in life tables for individuals under 60, but it is smaller for those older than 60, which suggests use of private information by older respondents.

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Our econometric analysis confirms that individuals use private information—mainly their parents' survival and longevity—to adjust their level of uncertainty. Finally, we find that SUL has a sizable impact, in addition to SLE, on risky behaviors: more uncertainty on longevity significantly decreases the probability of unhealthy lifestyles. Given that individual uncertainty about longevity affects prevention behavior, retirement decisions, and demand for long-term care insurance, these results have important implications for public policy concerning health care and retirement.

Keywords Subjective expectations · Uncertainty · Longevity · Prevention decisions · Retirement decisions

Expected Longevity: Uncertainty Matters

For a long time now, econometric analysis of choice data has been based on the assumption that decision-makers have rational expectations (Manski 2004). Yet, more accurate information about individual beliefs regarding longevity might provide a better understanding of observed behaviors—in particular, decisions relative to retirement, pension plan choice, demand for long-term care insurance, prevention behavior, or risky lifestyles. Another argument in favor of eliciting subjective life expectancies is that life tables provide limited information. They provide information about life expectancy by gender and age only, when individual life expectancy can also be influenced by parental longevity and personal health and lifestyle.

Many studies have examined survival expectations. Some of the data used in this literature result from direct questions on expected longevity (Brouwer et al. 2005; Hamermesh 1985; Hamermesh and Hamermesh 1983; Mirowsky 1999; Mirowsky and Ross 2000). Other studies have relied on subjective survival probabilities as collected by the Health and Retirement Study (HRS), the Survey of Health, Ageing and Retirement in Europe (SHARE), or other surveys (Bago d'Uva et al. [forthcoming](#); Bissonnette and de Bresser 2015; Delavande and Rohwedder 2011; Delavande et al. 2017; Hurd 2009; Hurd and McGarry 1995; Kutlu-Koc and Kalwij 2013; Liu et al. 2007; Peracchi and Perotti 2014; Perozek 2008; Post and Hanewald 2013). Most studies examining the relation between illnesses and subjective survival probabilities have shown that individuals make rational use of available information: illnesses lower subjective survival probabilities, and subjective survival probabilities are correlated with death rates observed in longitudinal data. Parental death appears to have an impact on subjective survival probabilities, especially for the parent of the same sex. Most studies have found smaller survival probabilities for women than for men despite women's larger actuarial probabilities. Using longitudinal data, Hurd (2009) showed that expectations were closely correlated with outcomes.

Most studies have focused on average expectations by subgroup. Few studies have addressed the between-individual dispersion of expectations.¹ To our knowledge, no studies have explored subjective uncertainty at the individual level. In a theoretical study, Edwards (2013) argued that individual uncertainty regarding longevity is an

¹ Post and Hanewald (2013) make an indirect estimation of subjective uncertainty on the basis of saving behavior.

important component of well-being along with subjective life expectancy, which is only an expected value. A survey by Delprat et al. (2016) confirmed that individuals are risk-averse with respect to longevity risk. This risk is likely to be of major importance to an understanding of individual decisions. For instance, a theoretical paper by Kalemli-Ozcan and Weil (2010) showed that if subjective uncertainty about longevity is large enough, an increase in life expectancy may induce people to retire earlier rather than later because they are sensitive to the increased probability of enjoying retirement.

We focus on individual uncertainty regarding longevity. We collected original data through a survey conducted in 2009 with a representative sample of 3,331 French people aged 18 or older.

For each individual, the survey recorded up to five subjective survival probabilities for several target ages that depend on the individual's current age: 50, 60, . . . , 90. We use these elicited probabilities to build indicators of subjective life expectancy (SLE) and of individuals' subjective uncertainty regarding their longevity (SUL). SLE is the first moment of each individual's subjective distribution of his or her own longevity. SUL is the standard deviation of this distribution. Like us, Wu et al. (2015) elicited several survival probabilities per individual. However, to the best of our knowledge, our study is the first to directly estimate individual uncertainty regarding length of life.

In this article, we provide a measure of individual uncertainty on longevity (SUL). We assess its magnitude and examine whether it varies with private information about, for example, diseases, parents' death, and individual risky behaviors.

In the following section, we discuss the meaning of uncertainty in the context of a survey designed to elicit subjective survival probabilities. We then summarize our survey methodology and describe the main features of our data. Our results on SLE are in accordance with the existing literature, which makes us confident in the quality of our survey. Moreover, our findings indicate that subjective uncertainty about longevity provides information that differs from information in life tables.

Then we examine how subjective life expectancy and uncertainty about longevity vary with indicators of health, socioeconomic characteristics, lifestyles, and parental death. Regarding SUL, we find that individuals adjust uncertainty on the basis of private information, particularly variables related to their parents'—and especially their fathers'—survival and longevity.

In addition, we examine whether uncertainty (i.e., SUL) adds something to subjective life expectancy (SLE) for the understanding of individual behaviors regarding unhealthy lifestyles. Without any causal interpretation of our results, we find that, along with SLE, SUL is significantly correlated with risky behaviors.

Finally, we conclude by reexamining issues in public policy concerning health and retirement in the light of our study. In particular, we argue that our results may explain why reforms that increase retirement age may face strong resistance.

Probabilistic Risk and Ambiguity

We use the individual survival probabilities elicited by our survey to build our measure of individual uncertainty regarding length of life.

The term “uncertainty” has several meanings. It can be used for probabilistic risk and for ambiguity. In our framework, three types of uncertainty can exist: (1)

individuals might be aware of their survival probabilities, and the resulting distributions imply a degree of risk relative to longevity; (2) individuals might be ignorant of or uncertain about their survival probabilities (ambiguity); and (3) the recorded probabilities are affected by elicitation problems that introduce noise (such as focal point answers).

In our survey, individuals are presented with intervals of probability values. For individuals whose ambiguous beliefs do not take a probabilistic form, this is a constraining exercise. For individuals whose ambiguous beliefs already take the form of probabilistic ranges, the exercise may still be difficult if their probability ranges do not coincide with the intervals proposed in the questionnaire. Both of these cases suggest that ambiguity in beliefs is likely to be accompanied by noise in the answers. In contrast, the questionnaire does not constrain the thinking of individuals with precise probabilistic beliefs, although their answers may still be subject to noise (e.g., focal points). We expect few respondents, if any, to fall into this third category, but it seems clear to us that noise and ambiguity will be associated in our survey because we have not tried to elicit ambiguity directly. However, we think focal point problems are limited in our context, as discussed later in the article.

Given this clarification, what are the possible drivers of between-individual differences in uncertainty about longevity? Of course, this uncertainty is based on the fact that age at death varies widely across people born the same year. People observe a variability of ages at death among their relatives. They identify with a peer group and adjust their beliefs regarding survival probabilities according to what they observe in the group. Another source of variability is private information about personal characteristics (genes) and behavior.² Last, some between-individual variability in uncertainty is attributable to the sources of ambiguity: differences in cognitive traits guiding the thought process leading from piecemeal knowledge to the probability guess in response to the questionnaire.

The contribution of this article is to study subjective uncertainty on longevity (SUL). We address the following questions. Is SUL particularly large? Does it vary with socioeconomic characteristics, diseases, and parents' death? Is it correlated with behaviors regarding unhealthy lifestyles or health insurance enrollment?

Although our main focus is uncertainty about longevity (SUL), we will devote some attention to SLE because a comparison of our results with the existing literature will enable us to validate our approach and survey.

Data

The Survey

Our data come from an original survey of a representative sample of the French population: 3,331 individuals aged 18 or older were interviewed in 2009 using a computer-assisted, face-to-face personal interviewing (CAPI) technique.

² Being a smoker increases the risk of lung cancer, which reduces the length of life dramatically. Because the onset of cancer is not certain, this may increase personal uncertainty on longevity.

The survey devotes a great deal of attention to health status, with questions on specific illnesses, self-assessed health, and individual lifestyle (smoking habits, alcohol consumption, height, and weight). The questionnaire then elicits subjective probabilities of survival at different ages and subjective joint distributions of income and health for future decades.³ The survey also provides rich information on individual trade-offs between income and health in order to measure equivalent income, as in Fleurbaey et al. (2013), Schokkaert et al. (2014), and Samson et al. (2017).

Elicitation of Subjective Survival Probabilities

Our strategy for eliciting survival probabilities follows Hurd and McGarry (1995) and Liu et al. (2007). Respondents were asked about their chance of being alive beyond a given age. For a respondent younger than 51, the first question was, “In your opinion, what is the percent chance that you will live beyond the age of 50?”

Respondents received a scale with 14 values: 0 %, 5 %, 10 %, 15 %, 20 %, 25 %, 30 %, 40 %, 50 %, 60 %, 70 %, 80 %, 90 %, or 100 %. “Don’t know” and “refusal” options were also offered. One answer was allowed. To improve our knowledge of subjective probabilities of survival at old ages, we offered more probabilities at the bottom of the scale.

After the first subjective survival question, the respondent was asked the same question again but for “more than 60” and then for the next decades up to “more than 90.” Hence, respondents younger than 51 were asked five survival questions, those between 51 and 60 were asked four questions, and those between 81 and 90 were asked one question only. Follow-up questions were constrained: probability values strictly greater than the answer given to the previous question were not proposed.⁴ Therefore, subjective survival probabilities weakly decrease with age by construction.

Let x_i denote the age at death (length of life) of respondent i . For a person under age 51, five probabilities are recorded:

$$\begin{aligned} p_{50,i} &= \Pr(x_i > 50), p_{60,i} = \Pr(x_i > 60), p_{70,i} = \Pr(x_i > 70), \\ p_{80,i} &= \Pr(x_i > 80), p_{90,i} = \Pr(x_i > 90). \end{aligned} \quad (1)$$

For a person aged 75, for instance, only $p_{80,i}$ and $p_{90,i}$ are recorded.

Computing differences between two adjacent probabilities leads to subjective probability of death in decade j : $\hat{p}_{j,i}$. Three assumptions are used to compute SLE and SUL for each respondent (see details in the [online appendix](#)).

Assumption 1: All respondents will live up to 40: $P(x_i > 40) = 1$.

Assumption 2: No respondent will survive after 100: $P(x_i > 100) = 0$.

Assumption 3: All deaths in a given decade j are supposed to occur at the average age of death (x^j) within the decade observed for people of the same sex in the population.

³ The latter are analyzed in a companion paper (Luchini et al. 2017).

⁴ This constraint was also imposed in Delavande and Kohler (2009) but is not found in HRS.

Subjective life expectancy SLE_i is defined as the expected value of x_i :

$$SLE_i = E_i(x_i) = \sum_j \widehat{p}_{j,i} x^j. \quad (2)$$

Subjective uncertainty about longevity SUL_i is given by the standard deviation of x_i :

$$SUL_i = \sqrt{V_i(x_i)}, \text{ with } V_i(x_i) = \sum_j \widehat{p}_{j,i} (x^j - E_i(x_i))^2. \quad (3)$$

Because of discretization, Eqs. (2) and (3) are likely to provide only approximations to the true expectation and standard deviation of individual length of life.

Figure A1 in the online appendix gives an idea of the relation between SUL and elicited probabilities. For individuals with a similar subjective life expectancy (between 60 and 70), people with high uncertainty declare probabilities of death that are rather even across decades, whereas people who are more certain declare a higher probability in one decade.

SLE_i and SUL_i can be computed only for individuals who answered all survival questions, which resulted in a sample of 2,856 individuals, or 85.9 % of the initial sample.⁵ We checked that our conclusions are not affected by a selection bias.

Information About Health

Our survey included questions on 45 diseases that the respondent might have experienced in the previous 12 months. The respondent could add any other illness, and the corresponding verbatim were coded in ICD-10 by three doctors. We asked our team of doctors to classify the large number of illnesses observed according to two criteria: whether they are chronic, and whether they might threaten life in the short run. This led to four categories of illnesses, which we call vital risk variables:⁶

- N: Illnesses that do not shorten or threaten life (e.g., lumbago)
- A: Acute illnesses with immediate death risk (e.g., depression)
- C: Chronic condition causing reduction in the length of life but no immediate death risk (e.g., hypertension, diabetes)
- AC: Acute and chronic illnesses causing an immediate death risk and reduction in length of life (e.g., asthma, myocardial infarction)

Our survey also contained questions on functional limitations in the last 12 months. At the end of that section came an overall question on self-assessed health (SAH_i) on the basis of a visual scale ranging from 0 to 100.

We created vital risk categories in order to examine the link between illnesses, SAH, SLE, and SUL. SAH is generally considered a good predictor of death risk. However, the link between SAH and death risk might be more complex, as shown by Case and

⁵ The response rate is similar for men (86.6 %) and women (85.5 %) and decreases with age. Detailed statistics regarding response rates are given in the [online appendix](#).

⁶ See Bahrami et al. (2011). The classification is detailed in the [online appendix](#).

Paxson (2005). Some conditions are painful (e.g., arthritis, lumbago, anxiety) but not life-threatening, whereas others are not so painful but have a larger impact on death rates (heart disease).

Descriptive Analysis

Basic Features of the Data

Table 1 displays the means of variables used in our econometric analysis, computed for men and women separately.⁷

Table 1 shows that women are more affected than men by illnesses that spoil life without shortening it: 53 % of them have three or more illnesses of type N, in contrast with 36 % of men. Women also have significantly more acute (type A) and acute and chronic (type AC) diseases than men. However, we do not observe significant difference between men and women in the prevalence of chronic (C) diseases.⁸ Regarding functional limitations, all indicators show that women are significantly more affected than men by activity limitations and pain.⁹

Table 1 displays information on lifestyles (see also Figs. A3–A5 in the online appendix). Women seem to be more “virtuous” with a significantly smaller proportion of smokers or drinkers than men. On the other hand, the proportion of people who are obese, severely obese, or of normal weight is not significantly different between men and women. However, more men are overweight (34 %) than women (22 %).

Parental death can influence individual beliefs regarding survival (Hurd and McGarry 1995; Liu et al. 2007). The figures in Table 1 give a striking picture of the mortality difference between men and women: age at death is lower for fathers than for mothers; half of the respondents have lost their fathers, but only one-third have lost their mothers.¹⁰

Subjective Survival Probabilities

Figure 1 displays our raw information: the distribution of subjective survival probabilities $p_{50,i}, \dots, p_{90,i}$ defined by Eq. (1) and given by respondents younger than the target (e.g., the distribution of $p_{60,i}$ among people aged 60 or younger). These figures are rather similar for men and women and show a noticeable dispersion. A large majority of respondents chose $p_{j,i} = 1$ for young target ages, but there is a wide spread in elicited probabilities for target ages beyond 70: individual assessments of the probability of surviving beyond age 70 differ more than for younger ages.

Elicited probabilities may suffer from focal point biases toward 0, 1, or 0.5. Hurd (2009) emphasized that a tropism of elicited probabilities toward 50 % might result in an understatement by respondents when the true probability is greater than 50 % and in an overstatement when it is lower than 50 %.

⁷ The sample can be deemed representative of the French population (Schokkaert et al. 2014).

⁸ Table A1 and Fig. A2 in the online appendix give more details.

⁹ All variables presented in Table 1 are based on self-reporting.

¹⁰ This difference in the proportion of deceased fathers and mothers results in part from the fact that husbands are generally older than their wives.

Table 1 Descriptive statistics

Category	Variables	Women	Men	<i>p</i> Value
Socioeconomic Characteristics				
Age	Age	47.75 (18.56)	46.61 (17.62)	.116
Gender	Gender	0.52	0.48	.000
Education	No diploma	0.12	0.08	.002
	Primary school certificate	0.12	0.09	.003
	Junior high school diploma	0.34	0.40	.003
	High school diploma	0.16	0.17	.769
	University ≤ 2 years	0.13	0.11	.048
	University ≥ 3 years	0.13	0.16	.033
	Other diploma	0.001	0.002	.426
	Income ≤ 875 €	0.29	0.21	.000
Income	Income $\in [875\text{€} - 1,290\text{€}]$	0.26	0.23	.167
	Income $\in [1,290\text{€} - 1,800\text{€}]$	0.24	0.27	.056
	Income $> 1,800\text{€}$	0.21	0.28	.000
Health insurance	National health insurance only	0.05	0.07	.018
	Complementary insurance	0.88	0.87	.323
	CMUC (complementary insurance for low-income individuals)	0.06	0.05	.045
Family situation	Marital life	0.55	0.62	.000
	At least one child	0.45	0.35	.000
Health				
Vital risks	0 illnesses of type N	0.14	0.22	.000
	1–2 illnesses of type N	0.33	0.42	.000
	≥ 3 illnesses of type N	0.53	0.36	.000
	0 illnesses of type AC	0.80	0.83	.033
	1 illness of type AC	0.16	0.13	.029
	≥ 2 illnesses of type AC	0.04	0.03	.794
	0 illnesses of type A	0.87	0.93	.000
	≥ 1 illness of type A	0.13	0.07	.000
	0 illnesses of type C	0.68	0.68	.934
	1 illness of type C	0.21	0.21	.728
	≥ 2 illnesses of type C	0.10	0.11	.520
Functional limitations	Difficulties walking	0.17	0.12	.000
	Bedridden	0.12	0.09	.003
	Difficulties in everyday activities	0.21	0.14	.000
	Pain	0.39	0.32	.0008
Lifestyles				
	Smoker (individual currently smokes)	0.32	0.40	.000
	Underweight ($\text{BMI} \leq 18.5$)	0.05	0.01	.000
	Normal weight ($18.5 < \text{BMI} \leq 25$)	0.51	0.49	.239
	Overweight ($25 < \text{BMI} \leq 30$)	0.22	0.34	.000

Table 1 (continued)

Category	Variables	Women	Men	<i>p</i> Value
	Obese ($30 < \text{BMI} \leq 35$)	0.11	0.09	.251
	Severely obese ($\text{BMI} > 35$)	0.07	0.06	.205
	No alcohol	0.34	0.19	.000
	Alcohol, no risk	0.63	0.75	.000
	Alcohol, risky behavior ^a	0.03	0.07	.000
Parent Death and Age of Death	Father alive (%)	0.47	0.48	.873
	Father alive (age)	63.4 (11.99)	63.7 (11.88)	.638
	Father deceased (age at death)	68.7 (15.43)	68.6 (14.67)	.913
	Mother alive (%)	0.64	0.66	.335
	Mother alive (age)	64.6 (13.29)	64.7 (12.99)	.848
	Mother deceased (age at death)	71.6 (17.64)	74.6 (15.67)	.004
Health and Longevity	SAH	72.12 (21.15)	75.85 (18.63)	.000
	SLE	78.79 (9.72)	77.32 (9.66)	.0002
	SUL	10.66 (5.48)	10.44 (5.04)	.316
Number of Observations		1,504	1,292	

Notes: The third column reports the *p* value of the test for difference between men and women. For continuous variables, standard errors are reported in parentheses.

^a For alcohol consumption, women belong to the “risky behavior” category if they drink more than 14 drinks per week. For men, the limit is 21 drinks per week.

We think focal point problems are limited in our framework. First, our questions give an explicit list of 14 possible probabilities, a formulation that should limit focal answers. Indeed, contrary to an open question eliciting a probability in the interval $[0, 100]$, many options are proposed to respondents, and no salient option is available in the middle, such as 50/50. In addition, as noted earlier, we give more options for low probabilities, which pushes 50 % from the middle to the right side of the list.¹¹ Second, our results show a small peak around 0.5, especially for target ages beyond 70. To check Hurd’s hypothesis, we compared average subjective probabilities by age and

¹¹ To check that the options we propose are not too constraining, we compared our elicited probabilities to those observed in Wave 2 of SHARE, which uses only one open question requiring a probability between 0 % and 100 %. We found that only 5 % of respondents gave a probability that does not belong to our list of 14 values.

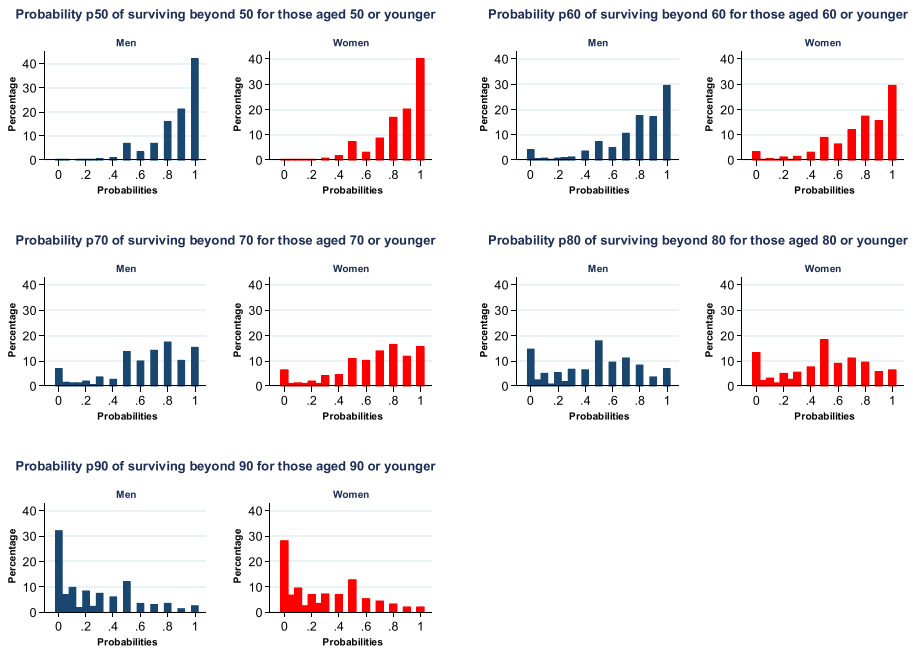


Fig. 1 Distribution of subjective survival probabilities, men and women of all ages below the target

target age with the corresponding survival probabilities in the life tables (see the [online appendix](#)). We found that Hurd's hypothesis does not hold for females: they systematically underestimate their survival probabilities, even when the true probability is lower than 50 %.¹²

Moreover, we do not think our data suffer from focal point biases toward 0 or 1. In Fig. 1, the proportion of probabilities equal to 1 decreases with the target age, a result that is not induced by any constraint in survey design.

Subjective Life Expectancy and Uncertainty

The average values by age of our variables of interest SLE and SUL, and of SAH, are displayed in Fig. 2 for men (continuous line) and women (dashed line).¹³ Sample means and standard deviations for the three indicators can be found at the bottom of Table 1.

As expected, SAH is continuously decreasing with age (Fig. 2). As in Case and Paxson (2005), women set their SAH at a lower average level than men. However, this difference appears to be significant only for women younger than 55.

SLE is increasing with age: individuals update their expectations when they survive to older ages. The dotted lines in Fig. 2 give life expectancies (LE) provided by the life tables for the year of our survey. These data, available via the French National Institute

¹² Elicited probabilities for men, however, might suffer from a bias toward 0.5.

¹³ The curves derive from locally weighted scatterpoint smoothing. For readability, confidence intervals are provided for men only.

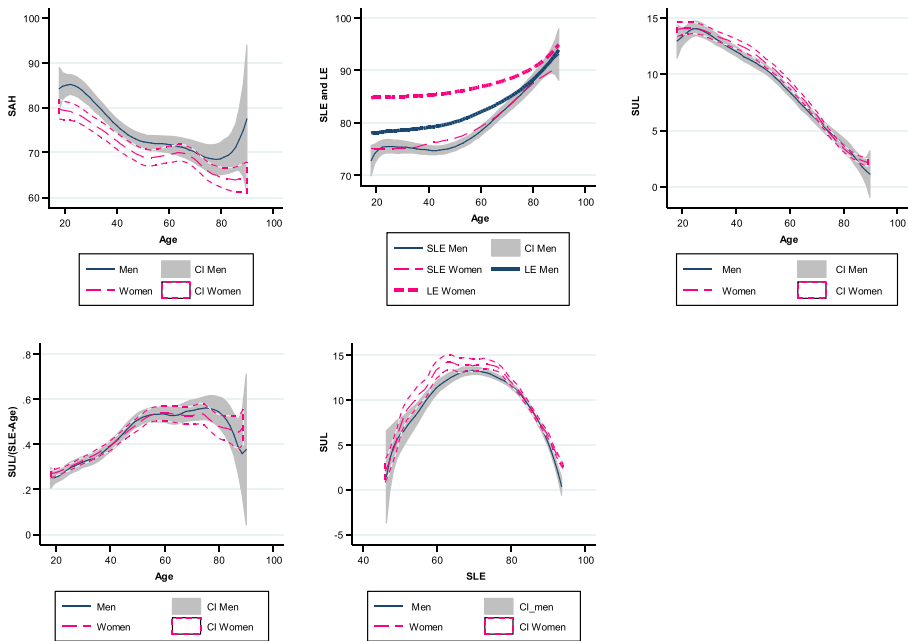


Fig. 2 Average self-assessed health (SAH), average subjective life expectancy (SLE) and life table LE, and average subjective uncertainty on longevity (SUL), by age and relationship between SLE against SUL

of Demography, are based on the mortality rates observed in 2009 for each generation. A large gender gap in life table LE is evident,¹⁴ yet this gender gap is not reflected in SLE. Male and female SLE are very close at every age except for a slight but significant difference between ages 40 and 55.

Males and females are both pessimistic: they underestimate their SLE in comparison with life table LE. The underestimation decreases with age and becomes nonsignificant after the age of 70 for men.¹⁵

Pessimism is much more pronounced for females than for males, a result commonly found in the literature using subjective survival probabilities (Delavande et al. 2017; Hurd 2009; Hurd and McGarry 1995; Liu et al. 2007) or direct assessments of longevity (Mirowsky 1999). Pessimism among both genders has not always been found in the literature. For instance, no evidence of pessimism for U.S. men was found in HRS data (Hurd and McGarry 1995). On the other hand, Wu et al. (2015) showed that Australian men and women are pessimistic about survival probabilities and that this pessimism disappears for men after age 70, a result very close to ours.

We observe noticeable between-individual variability in SLE, as shown in Table 2. The standard deviation by age of SLE is equal to 10.8 years for men aged 40. It is decreasing with age but still equal to 6.2 years for men aged 60. Actually, this

¹⁴ Actually, France is one of the countries with the largest gender gap in LE at birth. It amounts to 6.7 years in 2010, compared with 3.9 in the United Kingdom, 5 in the United States, and 6 in Japan.

¹⁵ We find the same results using French data from SHARE (Wave 2). Men and women underestimate their survival probabilities, with no significant difference between them. In fact, the underestimation might be even greater, given that official statistics are based on 2009 mortality rates and do not incorporate future progress in longevity.

variability is comparable to the standard deviation of age at death computed from life tables for 2009.

The subjective uncertainty on longevity SUL is the standard deviation of the individual subjective distribution of longevity. The sample mean of SUL is approximately 10 years and is not significantly different for men and women (Table 1). It is close to 12 years for people aged 40 and still equal to 9 years for people aged 60 (Fig. 2). SUL is necessarily decreasing with the respondent's age: as an individual advances on his or her survival curve, the range of possible values for longevity decreases. When SUL is normalized by remaining life expectancy, it is increasing until age 55 but is flat thereafter (Fig. 2).

How can we interpret the value obtained for SUL? Does it mean that our respondents are subject to a large uncertainty? To examine this question, we first compare the value of SUL with the standard deviation of age at death as observed in life tables. Table 2 displays the average SUL for men and women aged 40, 50, . . . , 80 and the corresponding standard deviations of age at death computed from life tables in 2009 (using the same definitions for decades).

We find that the average SUL is of the same magnitude as the variability of ages at death for the population aged 40 to 60. However, the result is different when our respondents reach age 70 or 80. Their uncertainty is then lower than what can be measured from life tables. For men and women aged 80, the average SUL is less than half of the standard deviation of age at death in life tables (Table 2). This can be explained by the fact that older individuals have better private information about their inherited health and the consequences of risky lifestyles. This information is more likely to be available after age 60, when parents' or friends' deaths are more frequent and chronic diseases have often been diagnosed (after age 50). This result indicates that subjective uncertainty about longevity provides information that is different from that in life tables.

Even though it is similar or reduced with respect to standard deviation observed in life tables, individual SUL might still carry a sizable amount of uncertainty. To examine this, we compute individual confidence intervals at 95 % for longevity $CI_i = [SLE_i \pm$

Table 2 Standard deviation (SD) of SLE by age, average SUL by age, and SD of age at death, by age from life table

	Age				
	40	50	60	70	80
SD of Age at Death (life table 2009)					
Men	12.1	10.9	9.5	9	10.8
Women	11.1	10.2	9.3	8.7	9.4
Average SUL (sample)					
Men	11.4	11.5	9.0	5.6	4.9
Women	12.9	11.5	9.4	6.1	3.8
SD of SLE (sample)					
Men	10.8	9.1	6.2	6.6	2.4
Women	11.5	8.6	7.4	5.1	4.0

$2SUL_i]$.¹⁶ For individuals aged 50 or younger, the average confidence intervals (CI) are [50.1, 101.5]. Examining the CI distributions, we find that the third quartile of the lower bound is equal to 60.0, and the first quartile of the upper bound is equal to 96.7. Hence, 75 % of individuals place their lower bound below 60 years, and 75 % place their upper bound above 96.7 years. These calculations indicate that for young people, the uncertainty is large enough for these confidence intervals to cover the whole range of possible life spans.¹⁷ This is true for people aged 50 or younger and for people aged 51–60.¹⁸ When respondents are older, confidence intervals are narrower, with average bounds equal to [86.1, 94.8] for people older than 80.

Figure 2 (fifth panel) shows that SUL evolves like an inverted U with respect to SLE. This is mostly true by construction, given the formulas of SLE and SUL. More notable are the sizable variations in levels of uncertainty across individuals, as shown by Fig. 3, which displays several distributions of SUL for different levels of SLE. Pessimistic and optimistic people have less uncertainty, compared with people with medium SLE. However, the most striking finding is the extent of variation in uncertainty between individuals.¹⁹

Do Subjective Life Expectancy and Uncertainty on Longevity Vary With Socioeconomic Characteristics, Diseases, Lifestyles, and Parents' Death?

In this section, we analyze the correlation between SLE and SUL and several “determinants.” In the next section, we examine how unhealthy lifestyles are associated with SLE and SUL. As in research on expectations, our estimates cannot be interpreted as measuring causal impacts because subjective expectations are likely to be correlated with behaviors through unobserved variables (Delavande et al. 2017). Causation in multiple directions is likely to occur for lifestyles. For instance, respondents in bad health may smoke or fail to exercise because they are pessimistic about their longevity prospects.

Actually, it is possible to formalize these multiple causations by considering that individuals choose between bundles of health and behaviors and have beliefs regarding the probability of health outcomes conditional on behavior. The interdependence between behaviors (risky lifestyles or prevention decisions) and beliefs can be explored using the following model,²⁰ where individuals maximize their expected utility:

$$\sum_{(h_i, b_i) \in Z_i} p_i(h_i; b_i) u_i(c_i(h_i, b_i), h_i, b_i), \quad (4)$$

where b_i is a particular behavior (e.g., smoking), c_i is individual consumption level, and h_i is individual health. The function $p_i(\cdot)$ is the belief function giving the probability of

¹⁶ The distribution of SLE is close to the normal distribution, with skewness equal to -0.7 and kurtosis equal to 3.3 .

¹⁷ This does not rule out variations in level of uncertainty across individuals, as shown in Fig. 3 and in the next section.

¹⁸ For people aged 51–60, the corresponding figures are [57.9, 97.1] for the average CI, 63.5 for the third quartile of the lower bound, and 91.9 for the first quartile of the upper bound.

¹⁹ We can also exhibit graphs of the SUL distribution for a unique level of SLE.

²⁰ This one-shot model can be easily extended to a life cycle perspective.

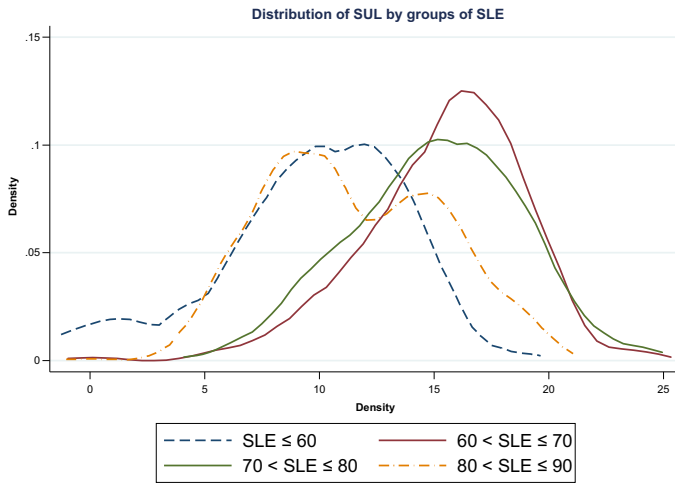


Fig. 3 Distribution of SUL by groups of SLE

health outcomes conditional on behavior, and $u_i(\cdot)$ is the utility function. The function $c_i(\cdot)$ depicts the budget possibilities of the individual under a particular health-behavior bundle. $\mathbf{Z}_i$ is the set of possible health-behavior bundles that the individual may obtain, including constraints on the choice of behavior b_i as well as possible health outcomes h_i .

The function $p_i(\cdot)$ reflects how the individual sees the health-behavior possibilities open to him or her. In particular, adopting a particular behavior b_i alters the probabilities of health outcomes. This function is shaped by two main sets of factors: (1) the objective circumstances of the individual, such as initial health condition, genetic endowment, and environment; and (2) the individual's cognitive dispositions, such as information about the incidence of health conditions under various behaviors, optimism, and various cognitive biases.

This simple model shows that beliefs and behaviors are interdependent and co-determined by individual circumstances, cognitive dispositions, and preferences.

Empirical Specification

We estimate a three-equation model separately for women and men:

$$SAH_i = \mathbf{VR}_i \alpha_1 + \mathbf{X}_{1,i} \beta_1 + \mathbf{Z}_i \delta + u_{1,i} \quad (5a)$$

$$SLE_i = SAH_i \gamma_2 + \mathbf{VR}_i \alpha_2 + \mathbf{X}_{2,i} \beta_2 + u_{2,i} \quad (5b)$$

$$SUL_i = SAH_i \gamma_3 + \mathbf{VR}_i \alpha_3 + \mathbf{X}_{3,i} \beta_3 + u_{3,i}, \quad (5c)$$

with $(u_{1,i}, u_{2,i}, u_{3,i})' \sim N(0, \Sigma)$, where Σ can be a nondiagonal matrix.

In Eq. (5a), SAH_i is explained by vital risk ($\mathbf{VR}_i$) variables; by $\mathbf{X}_{1,i}$, which includes a quadratic function of age, socioeconomic variables (education, income, and insurance

coverage), and variables characterizing individual lifestyle; and by $\mathbf{Z}_i$, the functional limitations experienced by the individual. SLE_i and SUL_i are explained by the subjective and objective indicators of health, SAH_i and $\mathbf{VR}_i$, and by a set of regressors $\mathbf{X}_{2,i}$ that contains the variables $\mathbf{X}_{1,i}$ and information about the death of the individual's parents.

Several specifications of the information relative to parents' death are considered. We apply four categories for fathers and mothers: alive or dead, with age unknown or not. When the age is known, we introduce the age of death (or current age for living parents) as a cross effect with the death (or with the indicator of a living parent).

We suppose that information about parental death and age at death does not influence SAH, and this is confirmed by preliminary regressions.

Most variables $\mathbf{X}_{1,i}$, $\mathbf{X}_{2,i}$, $\mathbf{VR}_i$, and $\mathbf{Z}_i$ are components of the private information individuals use to build beliefs regarding their subjective life expectancy and uncertainty.

The disturbances $u_{1,i}$, $u_{2,i}$, and $u_{3,i}$ in the three equations are likely to capture unobserved heterogeneity that might explain SAH_i , SLE_i , and SUL_i : (1) individual's information about health (hereditary diseases) or lifestyle not recorded in the survey; (2) heterogeneity in pessimism/optimism; or (3) in the personal weights individuals assign to vital risks and lifestyle to form their subjective assessment of health and survival probabilities. Our specification allows for correlations between the three disturbances.²¹

Results

Self-assessed Health

The first columns of Table 3 present the estimates of Eq. (5a) for women and men. To interpret these estimates, the reader should keep in mind that average SAH is 72 for women and 76 for men on a 0–100 scale. SAH determinants are not the focus of this study, but they enable us to check the validity of the survey.

The impacts of vital risks are quite large (see the online appendix, Section 4.4). Some are valued similarly by men and women; others have different impacts on men's and women's SAH.

Women and men are similarly aware of the deleterious impact of smoking, being overweight, and obesity on health. Men are a bit more aware about smoking. The estimated loss in SAH is 3.3 points for men and 2.0 points for women. Conversely, women ascribe greater losses in SAH to BMI problems. For alcohol, the only significant impact is a positive one: 3.0 points for nonrisky alcohol consumption by women (but not men).

Socioeconomic variables indicating a low social position are correlated with a significantly lower SAH: having less than a high school diploma for women (–4.0 to

²¹ Investigations detailed in the online appendix (Section 4) led us to reject the possibility of selection bias and not to reject the exogeneity of SAH_i for the SLE_i and SUL_i equations. Hence, we rely on a GLS estimator that allows for heteroskedasticity and correlations between the disturbances of Eqs. (5a)–(5c). Notice, however, that we perform the exogeneity test assuming that only SAH might be non-exogenous, which is rather contradictory with the idea that there are causations in multiple directions.

Table 3 GLS estimation of the three-equation model, women and men

	Women			Men		
	SAH (1)	SLE (2)	SUL (3)	SAH (1)	SLE (2)	SUL (3)
Age	-0.344* (0.143)	-0.280** (0.104)	0.015 (0.053)	-0.394** (0.144)	-0.269* (0.115)	0.030 (0.057)
Age Squared	0.003 [†] (0.001)	0.005** (0.001)	-0.002** (0.000)	0.003 [†] (0.002)	0.005** (0.001)	-0.002** (0.000)
Health						
SAH	—	0.084** (0.012)	0.008 (0.006)	—	0.114** (0.014)	-0.005 (0.007)
Vital risks						
0 illness of type N	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
1–2 illnesses of type N	-5.600** (1.423)	-0.146 (0.671)	0.827* (0.345)	-2.699* (1.120)	-0.475 (0.593)	0.133 (0.292)
≥3 illnesses of type N	-9.956** (1.427)	-0.766 (0.669)	0.744* (0.344)	-6.200** (1.243)	-0.976 (0.649)	0.175 (0.320)
0 illness of type AC	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
1 illness of type AC	-6.838** (1.250)	-1.344* (0.592)	-0.103 (0.304)	-3.638** (1.290)	-0.989 (0.684)	0.318 (0.337)
≥2 illnesses of type AC	-7.479** (2.590)	1.364 (1.213)	-0.261 (0.623)	-6.021* (2.389)	-1.468 (1.271)	0.426 (0.627)
0 illness of type A	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
≥1 illness of type A	-8.634** (1.422)	-1.243 [†] (0.666)	-0.222 (0.342)	-10.329** (1.680)	-2.114* (0.904)	-0.030 (0.446)
0 illness of type C	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
1 illness of type C	-1.717 (1.185)	-0.905 (0.556)	0.309 (0.285)	-3.778** (1.131)	-0.097 (0.603)	0.535 [†] (0.297)
≥2 illnesses of type C	-4.988** (1.704)	-2.681** (0.801)	-0.609 (0.411)	-8.919** (1.560)	-1.908* (0.841)	-0.435 (0.414)
Functional limitations						
Difficulties to walk: Yes	-4.516** (1.371)	—	—	-5.972** (1.435)	—	—
Bedridden: Yes	-2.292 (1.542)	—	—	-1.300 (1.620)	—	—
Difficulties in everyday activities: Yes	-5.506** (1.527)	—	—	-5.589** (1.585)	—	—
Pain: Yes	-3.377** (1.204)	—	—	-2.329* (1.104)	—	—
Parent Death and Age of Death						
Father alive	—	Ref.	Ref.	—	Ref.	Ref.
Father alive, age unknown	—	-1.449 (3.122)	6.283** (1.603)	—	0.109 (3.512)	5.765** (1.732)
Father alive, age	—	-0.007 (0.040)	0.058** (0.021)	—	0.078 [†] (0.046)	0.048* (0.023)
Father deceased	—	-1.381	4.858**	—	3.212	2.992 [†]

Table 3 (continued)

	Women			Men		
	SAH (1)	SLE (2)	SUL (3)	SAH (1)	SLE (2)	SUL (3)
		(3.046)	(1.564)		(3.488)	(1.720)
Father deceased, age unknown	—	1.090	0.077	—	2.244	0.614
		(1.805)	(0.927)		(1.950)	(0.962)
Father deceased, age	—	0.003	−0.002	—	0.021	0.004
		(0.022)	(0.011)		(0.025)	(0.012)
Mother alive	—	Ref.	Ref.	—	Ref.	Ref.
Mother alive, age unknown	—	1.749	−2.983 [†]	—	8.394*	−4.800*
		(3.397)	(1.744)		(3.883)	(1.915)
Mother alive, age	—	0.001	−0.025	—	0.020	−0.022
		(0.040)	(0.020)		(0.046)	(0.023)
Mother deceased	—	−4.263	−1.979	—	0.129	−1.956
		(3.075)	(1.579)		(3.890)	(1.918)
Mother deceased, age unknown	—	0.490	−0.219	—	−1.787	−0.621
		(2.080)	(1.068)		(2.443)	(1.204)
Mother deceased, age	—	0.027	−0.002	—	0.004	−0.003
		(0.023)	(0.012)		(0.028)	(0.014)
Lifestyles						
Smoker: Yes	−2.024 [†]	−1.956**	−0.122	−3.325**	−2.289**	−0.432 [†]
	(1.055)	(0.495)	(0.254)	(0.916)	(0.491)	(0.242)
Underweight	−0.939	−1.391	−0.453	−13.832**	4.476*	−1.934 [†]
	(2.089)	(0.985)	(0.506)	(3.980)	(2.147)	(1.059)
Normal weight	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Overweight	−2.725*	0.391	0.164	−1.510	−0.384	−0.006
	(1.117)	(0.525)	(0.270)	(0.972)	(0.521)	(0.257)
Obese	−3.423*	1.698*	0.322	−2.746 [†]	0.022	−1.214**
	(1.504)	(0.708)	(0.363)	(1.533)	(0.814)	(0.401)
Severely obese	−10.245**	−0.177	0.043	−8.559**	−0.806	−1.236*
	(1.828)	(0.865)	(0.444)	(1.870)	(1.001)	(0.493)
No alcohol	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Alcohol, no risk	2.986**	1.124*	−0.181	1.278	1.319*	0.052
	(0.977)	(0.459)	(0.236)	(1.100)	(0.586)	(0.289)
Alcohol, risky behavior	−0.955	0.475	0.104	−0.668	−2.281*	0.134
	(2.830)	(1.330)	(0.683)	(1.899)	(1.017)	(0.501)
Sociodemographic Characteristics						
Education						
No diploma	−3.546*	−0.541	0.066	−3.093*	−0.811	−0.513
	(1.806)	(0.854)	(0.439)	(1.865)	(0.993)	(0.490)
Primary school certificate	−5.626**	−0.342	0.441	−1.853	−1.851 [†]	−0.256
	(1.866)	(0.880)	(0.452)	(1.916)	(1.019)	(0.503)
Junior high school diploma	−4.018**	−1.190 [†]	0.962**	−0.848	−2.621**	−0.596 [†]
	(1.365)	(0.643)	(0.330)	(1.245)	(0.663)	(0.327)

Table 3 (continued)

	Women			Men		
	SAH (1)	SLE (2)	SUL (3)	SAH (1)	SLE (2)	SUL (3)
High school diploma	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
University (≤ 2 years)	-0.681 (1.640)	0.920 (0.770)	1.063** (0.395)	1.224 (1.643)	-1.539 [†] (0.874)	-0.669 (0.431)
University (≥ 3 years)	-2.918 [†] (1.680)	0.945 (0.789)	0.427 (0.405)	0.985 (1.514)	-0.467 (0.801)	0.156 (0.395)
Other diploma	-29.714* (13.743)	-3.216 (6.465)	0.702 (3.320)	-13.057 (8.335)	3.628 (4.440)	1.593 (2.189)
Income						
Income $\leq 875\text{€}$	-4.077** (1.381)	-1.178 [†] (0.651)	-0.189 (0.334)	-2.473 [†] (1.313)	-0.714 (0.700)	-1.375** (0.345)
Income $\in [875\text{€}–1,290\text{€}]$	-3.194* (1.276)	-0.416 (0.601)	0.036 (0.309)	-0.759 (1.189)	0.069 (0.630)	-0.589 [†] (0.311)
Income $\in [1,290\text{€}–1,800\text{€}]$	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Income $>1,800\text{€}$	-0.960 (1.342)	-0.054 (0.631)	-0.283 (0.324)	0.323 (1.166)	-1.216 [†] (0.622)	-0.444 (0.307)
Health Insurance						
National health insurance only	-1.278 (2.168)	-0.868 (1.020)	1.020 [†] (0.524)	-2.534 (1.650)	0.814 (0.879)	0.112 (0.433)
CMUC	2.246 (1.988)	-0.379 (0.930)	0.314 (0.478)	-5.493* (2.181)	-4.462** (1.168)	0.238 (0.576)
Complementary insurance	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Family situation						
Single	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Marital life	0.743 (1.028)	0.607 (0.482)	0.494* (0.248)	1.341 (1.024)	-0.042 (0.546)	0.061 (0.269)
No child	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
At least one child	0.334 (1.045)	-0.098 (0.495)	-0.216 (0.254)	1.387 (1.065)	-0.867 (0.571)	-0.111 (0.281)
Constant	101.041** (3.569)	74.922** (2.321)	11.048** (1.192)	99.157** (3.388)	66.323** (2.560)	13.877** (1.262)
$\rho_{1,2}$		-0.002			0.011	
$\rho_{1,3}$		-0.012			-0.014	
$\rho_{2,3}$		-0.293**			-0.235**	
R^2	.353	.316	.446	.359	.340	.408
SD of Dependent Variable	21.04	9.61	5.48	18.45	9.69	5.05
RMSE	16.91	7.95	4.08	14.77	7.87	3.88
N		1,504			1,292	

Note: Standard errors are shown in parentheses.

[†] $p < .10$; * $p < .05$; ** $p < .01$

–5.6 points), an income below 875€ for men and women (–2.5 to –4.1 points), or being a CMUC²² beneficiary for men (–5.5 points).

Subjective Life Expectancy

Results concerning SLE (Eq. (5b)) are presented in Table 3, column 2. Average SLE is 78.8 years for women and 77.3 years for men with standard deviations equal to 9.7 for both women and men (see Table 1). Individuals take SAH into account when determining their survival probabilities: a 10-point increase in SAH raises SLE significantly by 0.8 years for women and 1.1 years for men.

The estimated impacts of vital risks and lifestyle on SLE are direct effects that come on top of the indirect impacts via SAH in Eq. (5a). For women, having one illness of type AC or at least one illness of type A reduces SLE by 1.3 years. For men, type AC illnesses have no significant impact on SLE, whereas having at least one type A illness shortens SLE by 2 years. Interestingly, both women and men ascribe a large loss in life expectancy to having two or more illnesses of type C. Women and men, respectively, associate a loss in SLE equal to 2.7 years and 1.9 years (which are not significantly different). If we compute the total effect of having two or more chronic illnesses (a direct effect plus an indirect effect through SAH), we find a loss of 3 years for women and men. An interesting result is that illnesses of type N have no impact on SLE for men or women.²³ Individuals do not adjust their survival probabilities (and, accordingly, their SLE) for illnesses of type N, but they do expect a reduction for chronic diseases. This suggests that they are reasonably well-informed regarding the impacts of illnesses on longevity.

The estimated impact of lifestyles also shows that individuals are well informed. In our multivariate analysis, we find that smoking reduces life expectancy by 1.9 and 2.3 years, respectively, for women and men. Comparing the mean SLE directly between smokers and nonsmokers, we find significant differences of 5.7 and 5.8 years for men and women—losses in SLE that are consistent with the epidemiological results.

Only men appear to be conscious of the influence of heavy drinking on longevity (2.3 years reduction in SLE). The results for BMI are striking. BMI problems lead to a much lower SAH, and they have a negative effect on SLE through this channel. On top of this indirect effect, however, individuals are not aware that a high BMI can directly shorten life. On the contrary, after controlling for SAH, obese women expect 1.7 more life years than other women. Although the sum of the direct and indirect effects remains negative, this result suggests that for women, obesity has a larger effect on the perceived quality of life than on longevity.²⁴

Some studies have shown that the longevity of the same-sex parent has an influence on individual survival probabilities (Liu et al. 2007). We find a slightly different result: women's SLE is not influenced by any of the parent death variables. For men, SLE is positively correlated with their fathers' survival (+5 years if we use the average age of

²² Means-tested free complementary health insurance.

²³ The classification of illnesses (N, C, A, or AC) was not communicated to the respondents, nor was the information that a given illness does or does not shorten or threaten life.

²⁴ Endogeneity of lifestyle may also play a role if some of the less-healthy women are more careful about their weight.

men's surviving fathers (63.7; see Table 1) and mothers' survival (but only if their mother's age is unknown, which concerns very few men).

Finally, the effects of socioeconomic variables show that individuals with little education or a low social position foresee a shorter life for themselves. Women with monthly income below 875€ or only a junior high school diploma have a reduction in SLE equal to 1.2 years; men who are CMUC beneficiaries have a reduction in SLE of 4.5 years. Thus, our respondents form their expectations on the basis of information that is consistent with the observed correlation between social position and longevity.

Subjective Uncertainty on Longevity

Results concerning SUL are displayed in column 3 of Table 3. On average, SUL is equal to about 10.5 years for men and women. As already explained, age has a mechanical negative impact on SUL. Our results show how individuals use private information to form their expectations. Computing the Fisher statistic to test for the significance of all variables except age, we find small but significant Fisher statistics equal to 1.49 for women ($p = .029$) and 2.11 for men ($p = .0001$). The fact that some of the regressors have a significant impact suggests that uncertainty is not only attributable to ambiguity.

One remarkable result is that the main determinants of SUL are variables related to parents'—and especially, fathers'—survival and longevity.²⁵ They have large impacts of the same sign for men and women. Uncertainty increases when fathers are deceased (by 4.9 for women and 3.0 for men). When fathers are alive, uncertainty increases with the age of the parent. At the average ages given in Table 1, we obtain increases of 3.7 for women and 3.0 for men. This confirms that individual uncertainty is based in part on the longevity or survival individuals observe in their group of reference (here, parents).

Other explanatory variables have a significant but smaller impact on SUL. For example, having diseases of type N slightly increases uncertainty for women. Having an income below 875€ decreases uncertainty for men (by 1.4). Unhealthy lifestyles can have a negative and significant impact on SUL for men; for example, uncertainty decreases by 1.2 for obese and severely obese men. However, we find no correlation between lifestyles and SUL for women.

The estimates of the correlation coefficients between the disturbances of Eq. (5) are displayed at the bottom of Table 3. As expected, $\rho_{1,2}$ and $\rho_{1,3}$ are not significantly different from 0, which confirms the exogeneity of SAH. (The unobserved heterogeneity that contributes to the formation of SAH is not correlated with the unobserved heterogeneity that influences SLE and SUL). On the other hand, $\rho_{2,3}$ is significant and negative for women and men, suggesting that a lower SLE for given regressors, which we roughly equate with pessimism concerning life expectancy, is correlated with a higher individual uncertainty on longevity.²⁶

²⁵ Mothers' survival and longevity have a more limited impact, which might be explained by the fact that a mother's death generally occurs later in individuals' lives. In our sample, two-thirds of mothers, but less than one-half the fathers are still alive (Table 1).

²⁶ While controlling for all the regressors, we find that SUL residuals are an inverse U-shaped function of SLE residuals. This results partly from the definition of our indicators (see Fig. A9 in the online appendix).

Risky Behaviors and Subjective Uncertainty on Longevity

As Delavande et al. (2017) noted, one reason for studying subjective expectations is to understand individual decisions under uncertainty. Our goal is to determine whether uncertainty (i.e., SUL) adds something to SLE in the understanding of individual behaviors regarding unhealthy lifestyles and complementary health insurance subscription. Our survey does not provide information on other financial decisions.

Adopting a simple regression framework, we estimate different linear probability models, where behaviors such as smoking, drinking, being obese (or severely obese), and enrollment in a complementary health insurance plan are explained by SUL and SLE. All regressions include the same sociodemographic characteristics and health variables as before, controlling for the circumstances the individual faces. Regressions are run separately for men and women, and results are displayed in Table 4. We do not make any causal interpretation of our results but analyze them as correlations only. Indeed, there is causality in both directions between beliefs and behaviors, and the appropriate model should consider that individuals choose between health-behavior bundles, as described in the previous section.

We find that SLE is negatively correlated with all risky behaviors for men and with being a drinker for women. Interestingly, SUL is also significantly correlated with smoking for men and women: those who are more uncertain are less likely to smoke. One additional standard deviation of SUL decreases the probability of smoking by 4.03 percentage points for men and 2.7 percentage points for women. These impacts are sizable, given the proportions of smokers in our sample (40 % for men and 32 % for women). They are also sizable in comparison with the impact of an increase of SLE by 1 standard deviation, which decreases the probability of smoking by 8.7 percentage points for men and 6.8 percentage points for women.

For men, we find that more uncertainty (1 standard deviation) significantly decreases the probability of being obese by 5 percentage points and the probability of being severely obese by 2 percentage points. For women, tobacco use is the only unhealthy lifestyle influenced by SUL or SLE.²⁷

These results show that like SLE, SUL is correlated with decisions regarding risky behaviors. This means that public health messages focusing exclusively on longevity improvements miss something.

How can we interpret the positive impact of SUL on healthy behaviors? Consider a more formal model of lifetime utility in which expected utility is equal to

$$U(c_1, b_1) + \sum_{t>1} p_t(b_1, \dots, b_{t-1}) U(c_t, b_t), \quad (6)$$

where c_t and b_t are consumption and behavior (e.g., smoking) in period t , and $p_t(\cdot)$ is the probability of being alive in period t (as a function of smoking in the previous periods). In this model, $SLE = 1 + \sum_{t>1} p_t$; and for a given SLE, maximum SUL obtains when p_t is

²⁷ The results regarding complementary insurance are not conclusive, but enrollment is not much a matter of individual decision in France. One-half the population is covered by employer-provided plans, and 6 % of the population is covered for free by plans for low-income people.

Table 4 OLS estimation of the impact of SLE and SUL on risky lifestyles, women and men

	Smoker	Obese + Severely Obese	Severely Obese	Drinker	Complementary Insurance
Women					
SLE	-0.007** (0.001)	0.002 (0.001)	-0.001 (0.001)	-0.000 (0.001)	0.001 (0.001)
SUL	-0.005† (0.003)	0.002 (0.002)	-0.001 (0.002)	0.000 (0.001)	-0.004† (0.002)
Control variables	Yes	Yes	Yes	Yes	Yes
<i>N</i> for <i>y</i> = 1	440	187	84	43	882
Men					
SLE	-0.009** (0.002)	-0.001 (0.001)	-0.002* (0.001)	-0.004** (0.001)	-0.000 (0.001)
SUL	-0.008* (0.003)	-0.010** (0.003)	-0.004* (0.002)	-0.002 (0.002)	0.001 (0.003)
Control variables	Yes	Yes	Yes	Yes	Yes
<i>N</i> for <i>y</i> = 1	452	156	117	105	753

Note: Control variables include all variables presented in Table 3, except lifestyle variables.

† $p < .10$; * $p < .05$; ** $p < .01$

constant over time (either one dies early or one enjoys the maximum life span).²⁸ In this framework, the relevant statistic for the evaluation of improvements in survival probabilities is generally not SLE but is instead $\sum_{t>1} p_t u_t$, where u_t is the utility enjoyed in t .

SUL is the standard deviation of the subjective distribution regarding individual longevity. An exogenous increase in SUL means that the relative weight of per-period utility is spread over time, reducing the probability weight of middle-age utility in favor of old-age utility. This induces the individual to spread consumption plans from middle age to old age, with two effects.

First, this shift in utilities due to consumption plans makes survival to old age more attractive, which may induce behavioral change that shifts the probability of living further, from middle age to old age, triggering a mechanism by which both probabilities and utilities are shifted toward old age. Second, an exogenous spread in probabilities reflecting an increase in standard deviation has no direct impact on precautionary behavior, given that the latter depends on the marginal impact of precautions on survival probabilities, not on the absolute levels of these probabilities. However, there is an indirect impact. Healthy behavior has more value if the future periods at which survival chances are increased have greater utility, and this will be the case because of the mechanism described earlier. By this indirect mechanism, greater standard deviation in individual expectations, other things

²⁸ p_t is the probability of being alive at period t , and $p_t - p_{t+1}$ is the probability of dying at the end of period t . If $p_t = p_{t+1}$, there is no risk of dying in t . Hence, a constant p_t sequence means that there are only two periods at which one can die: namely, the first and the last. This gives maximum dispersion to the distribution of ages at death. Contrary to Eq. (4), where the function $p_t(h_t; b_t)$ was the subjective probability of different health states conditional on behavior, here $p_t(b_1, \dots, b_{t-1})$ is the probability of being alive in t , conditional on behavior in previous periods. We consider only two health states: alive or dead.

being equal (keeping life expectancy fixed), induces greater incentives for healthy behavior for individuals who are able to shift consumption plans toward the future.

Conclusion

To study individual uncertainty about longevity, we have designed and conducted a survey to elicit survival probabilities on a sample representative of the French population.

We find that SLE values are characterized by a large between-individual variability, which seems consistent with actual inequality in longevity. Econometric estimations show that individuals are quite rational in adjusting their survival probabilities with respect to their illnesses, lifestyles, and social position.

Subjective uncertainty on longevity (SUL), on average, is equal to more than 10 years for men and women. Comparing the average SUL to what is observed in life tables for the whole population, we find that SUL is of the same magnitude as the variability of ages at death for the population aged 40–60 but that it is smaller for respondents older than 60. The latter are more certain about their longevity, which suggests use of private information.

Our econometric analysis confirms that individuals use private information, mostly their fathers' age at death, or their fathers' age if he is still alive, to adjust their level of uncertainty. Additional econometric findings show that SUL is correlated, for a given SLE, with risky behaviors. More uncertainty on longevity is associated with a significantly lower probability of an unhealthy lifestyle.

We find that the average level of SUL has a magnitude that is comparable to the variability of longevity observed in life tables for people younger than 60. Even though it is realistic, this value can be deemed large. Indeed, individual confidence intervals at 95 % for longevity indicate that for people younger than 60, SUL is large enough for these confidence intervals to cover the whole range of possible life spans. These expectations shed light on the reasons why people are reluctant to buy long-term care insurance, especially before age 60 (when such a purchase is theoretically more advantageous). Similarly, they help in understanding why pension reforms are difficult to justify on the basis of an increase in life expectancy only.

These results are relevant to issues of public policies concerning health and retirement. Indeed, individual uncertainty about longevity affects prevention behavior, retirement decisions, pension plan choices, and demand for long-term care insurance.

Regarding prevention, people are generally aware that they can lose a few years of life if they smoke. In a pioneering paper, Hamermesh and Hamermesh (1983:912) claimed that the fact “that smoking has not ceased entirely reflects people’s willingness to take risks, not imperfect information about the effects of smoking.” Public health advice focuses on life expectancy, but it is not obvious that this is the relevant statistic for individuals concerned about their health and longevity. Our results show a large between-individual variability in SLE, a large SUL, and the sensitivity of risky behaviors to SLE and SUL.

What does this imply for individuals' perception of the health benefits of prevention and healthy behavior? In our lifetime utility model (Eq. (6)), endogeneity of consumption plans makes the assessment of prevention effects depend on current beliefs. With

maximum uncertainty (constant p_t), the optimal consumption plan is quite flat, inducing a rather stable u_t over time, making SLE a reasonable proxy for $u_1 + \sum_{t>1} p_t u_t$. In contrast, with a declining p_t sequence, as in our data where SUL is large but far from maximal, the optimal consumption plan also displays a declining profile, inducing a declining u_t and making p_t less relevant for late periods of life. Such a situation may generate a mismatch between public health messages centered on life expectancy and the improvement of survival probabilities in old age on one hand, and the focus of individuals on risks that occur earlier in life on the other hand. Moreover, as shown in the last section, for a given SLE, prevention behaviors are likely to be encouraged by greater uncertainty.

Let us now consider insurance decisions. Income insurance is attractive, but if people are not sure to live long, this uncertainty may justify their apparent myopia. Why save a lot if you may not live to enjoy it? Our results might shed light on the “annuity puzzle” posed by the lack of success of annuities in spite of the fact that they insure individuals against the risk of outliving their savings. Assuming that they are actuarially fair, annuities should dominate ordinary bonds, at least under complete markets (Davidoff et al. 2005). As Beshears et al. (2014) noted, the literature has found several possible explanations, such as adverse selection, bequest motives, uncertain healthcare expenses, and the presence of default annuities embedded in retirement plans. If individuals are highly uncertain about their longevity, and if income support alleviates the danger of dire poverty after exhaustion of savings, the risk of dying early may loom larger than the risk of living too long. In this context, annuities increase the risk of not being able to take advantage of one’s wealth. This may look particularly unappealing to people who have had early health warnings, who would like to consume more than planned when they can still enjoy certain forms of expensive consumption (e.g., travel). Beshears et al.’s (2014) survey reveals people’s strong desire to remain in control of their wealth, which is completely consistent with anxiety about an early death.

Decisions about retirement age may also be affected by uncertainty about longevity. As noted earlier, Kalemli-Ozcan and Weil (2010) showed that if SUL is sufficiently large, an increase in SLE may have the paradoxical effect of decreasing retirement age. This is due to the fact that individuals are more likely to reap the benefits of retirement when longevity increases, thereby inducing people to retire earlier. In contrast, under low SUL, an increase in SLE simply induces a postponement of retirement. The probability of enjoying retirement is not affected; only its duration is at stake.

The political economy of pension policy is likely to be affected by a high uncertainty and a large between-individual dispersion in subjective life expectancy. Raising the legal age of retirement when longevity increases would seem acceptable, even logical, if everyone’s expectations coincided with the average LE and if SUL was low. However, if a sizable fraction of the population has a low SLE and/or a high SUL, raising the age of retirement reduces the probability of enjoying retirement for these people and may go directly against their rational wish (Kalemli-Ozcan and Weil 2010) to retire earlier when SLE rises. Therefore, the public outrage triggered by pension policies based on average longevity, which ignores the dispersion and uncertainty affecting individual situations, is not surprising.

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