Preferences for Life-Expectancy Gains: Sooner or Later?

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Abstract

We assess individuals' preferences for time paths of reductions in mortality risk yielding a life-expectancy gain of about one month. Using data from a survey of more than 1000 French residents, we find substantial coherence and heterogeneity. We elicit pairwise preferences between three perturbations of age- and gender-specific survival curves: transient (reduce hazard for next ten years), additive (reduce hazard in all years by an additive constant) and proportional (reduce hazard in all years by a multiplicative constant). The preference order implied by these pairwise responses is transitive for 85 percent of respondents. The most common preference orders, accounting for over 53 percent of respondents, are strict indifference, proportional ≻ additive ≻ transient, and the inverse of that ranking. These preference orders are consistent with globally risk-neutral, risk-seeking, and risk-averse preferences toward longevity, respectively. Choices between one of these scenarios and a latent version that provides no risk reduction for the first 10 or 20 years are consistent with these risk postures. Preferences toward the time path of mortality-risk reduction are not strongly associated with individual characteristics, although respondents who are older or exhibit higher consumption-discount rates tend to exhibit less longevity-risk aversion.

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JEL classification: D6, J17

Interventions that reduce mortality risk differ in the time path over which risk is reduced. Transient interventions reduce risk for a limited duration, e.g., the risk of fatality during a particular airplane flight or road trip or during a disease epidemic, earthquake, or other temporary condition. Other interventions offer a continuing risk reduction. The reduction may be roughly constant as an individual ages or it may increase in proportion to baseline mortality risk, which typically rises with age. Examples of a constant risk reduction might include improvements in transportation safety or protection from relatively exogenous risks (fires, earthquakes, hurricanes). Examples of a risk reduction that increases with baseline risk include interventions that reduce risks of cardiovascular disease or cancer.

The effects of these interventions may be summarized using a variety of metrics, e.g., the gain in life expectancy ("life years saved"), the reduction in mortality risk over some defined period ("lives saved"), the expected gain in quality- or disability-adjusted life years, or the increase in survival through some defined horizon (e.g., the five year survival rate). However, each of these summaries provides incomplete information about the risk reduction and individuals may have preferences over alternative risk reductions offering the same improvement as measured by a particular summary. For example, McNeil et al. (1978) found that 12 of 14 lung-cancer patients were risk-averse with respect to longevity for periods of zero to 25 years; for many, choosing radiation therapy over surgery yields a greater expected utility of longevity even though surgery provides both a larger five year survival rate and greater life expectancy.

This study investigates individual preferences for reductions in mortality risk that differ in how the reduction is distributed over time. It examines how these preferences are related to characteristics of the individual's preference structure: his risk posture (i.e., risk aversion, risk neutrality, risk seekingness) with respect to longevity, discount rate, degree of aversion to financial risk, and age-specific value per statistical life (VSL). The study applies the risk-tradeoff approach, in which survey respondents choose between alternatives that differ in health risk holding other attributes constant. Risk-tradeoff studies provide a useful complement to contingent valuation and choice experiments in which individuals evaluate tradeoffs between disparate dimensions (e.g., health risk and money). Because tradeoffs are restricted to dimensions that are more commensurable, respondents may find it easier to evaluate the choices and to provide more-valid responses. Risk-tradeoff methods have been used to evaluate preferences for various health risks, including different forms of mortality risk (e.g., Viscusi et al. 1991, Magat et al. 1996, Carthy et al. 1999, Chilton et al. 2006, Van Houtven et al. 2006).

This study extends the work of Nielsen et al. (2010) who asked survey respondents to choose between alternative improvements to their hazard functions offering the same gain in life expectancy. Like Nielsen et al., we consider three primary changes to the hazard function: transient (reducing risk over the next decade); additive (reducing risk by subtracting a constant in all future decades); and proportional (reducing risk by multiplying by a constant in all future decades). From the pairwise choices, we determine each respondent's preference ordering over the three scenarios. In addition, we investigate respondents' preferences between these three interventions and latent or delayed versions in which the risk reduction does not begin for 10 or 20 years.

Our sample is considerably more general than that of Nielsen et al., who included only 129 residents of Newcastle, UK who were approximately 40 years old. In contrast, our sample includes more than 1000 individuals, aged 20 to 69 years, representative of the French population. In addition, while Nielsen et al. studied preferences over risk reductions offering a life-expectancy gain of 6 months, which requires a very large risk reduction,[1] we asked survey respondents about a life-expectancy gain of about one month, which is more realistically achievable.

We find substantial coherence and heterogeneity in preferences with respect to the time pattern of mortality-risk reduction. Responses to the pairwise choices are consistent with a transitive preference ordering for a large majority (85 percent) of respondents. The most common preference orderings are consistent with global risk neutrality (23 percent), risk seekingness (16 percent), and risk aversion (14 percent) with respect to longevity. Preferences between one of these scenarios and a latent version (which offers no risk reduction for 10 or 20 years followed by a larger transient, additive, or proportional risk reduction offering the same life-expectancy gain) are generally consistent: risk-seeking respondents prefer the latent scenario, risk-averse respondents prefer the original, and risk-neutral respondents are indifferent. We find limited evidence for a systematic relationship between preferences over mortality-risk reductions and individual characteristics.

[1] In a review of life-expectancy gains associated with various medical interventions, Wright and Weinstein (1998) identified only two that offer gains as large as six months when applied to the general population: quitting cigarette smoking and a significant exercise program.

Individuals who are younger or have a low discount rate are more likely to exhibit risk-seeking preferences.

The paper is organized as follows. In Section 1, we present background information on survival curves and preferences over longevity. Section 2 describes the survey instrument and administration. Section 3 provides results, including the patterns of pairwise choices, preference orderings, and regression models to describe these results. Conclusions are in Section 4.

1. Survival curves and preferences

For an individual, let

f(t) be the probability density of dying at time *t*,

s(t) be the survival function (the probability of not dying before *t*), and

h(t) be the hazard function (the probability of dying at *t* conditional on survival to *t*).

Then

$$s(t) = 1 - \int_0^t f(\tau)d\tau, \quad (1)$$

and

$$h(t) = \frac{f(t)}{s(t)}. \quad (2)$$

Life expectancy at time 0 is the expected number of future life-years,

$$LE = \int_0^\infty tf(t)dt = \int_0^\infty s(t)dt, \quad (3)$$

where the second expression can be obtained upon integrating by parts, noting that $f(t) = -\frac{d}{dt}s(t)$.

Consider an individual who evaluates mortality risks by the expected utility of longevity,

$$V = Eu(t) = \int_0^\infty f(t)u(t)dt, \quad (4)$$

where *u(t)* is the utility of living until time *t* and is normalized so that *u(*0*)* = 0.

If *u(t)* is linear, the individual is risk neutral with regard to longevity and indifferent among all survival curves with equal life expectancy. Alternatively, if *u(t)* is concave, he is risk-averse with respect to longevity and prefers shifts to his survival curve that (holding life expectancy constant) reduce uncertainty about the time of death (i.e., shifts that “rectangularize” the survival curve, yielding a survival curve nearer 1 for t < T and nearer 0 for t > T, where T is the likely time of death). If *u(t)* is convex, he is risk-seeking with respect to longevity and disprefers shifts that rectangularize the survival curve (holding life expectancy constant).[2]

In general, an individual's risk preferences with respect to longevity can differ for values of *t* in different intervals; e.g., he could be risk-seeking for short and risk-averse for long values of longevity. Risk aversion, neutrality, and seekingness are characterized by whether the second derivative of the function *u(t)* is negative, zero, or positive, respectively. Higher-order derivatives may also be relevant, e.g., downside risk aversion (positive third derivative; Menezes et al. 1980) characterizes a preference for survival curves where uncertainty about time of death is smaller for earlier than for later dates.

Preferences for longevity may also depend on other attributes that vary with time, such as health and consumption. Quality-adjusted and disability-adjusted life years weight each time period by a factor that reflects health, with time lived in good health counting as more desirable than time lived in poor health (Pliskin et al. 1980, Hammitt 2013). Similarly, the utility associated with being alive at time *t* may depend on consumption of goods and services, and hence indirectly on wealth or income (Jones-Lee 1974, Hammitt 2000, 2002). An individual can influence his future consumption opportunities by saving. Hence his preference for an improvement to his survival curve that extends his life expectancy or increases uncertainty about his time of death may depend on how much he has saved for future consumption and the terms on which he can use annuities or other tools to manage the financial risk of outliving his savings (Drèze 1962, Rosen 1988).

Although it is reasonable to assume individuals are weakly risk averse with regard to wealth,[3] there is no such presumption concerning risk posture with respect to longevity. Empirical evidence suggests some people are globally risk-averse, risk-neutral, or risk-seeking with respect to longevity; for others, the degree and even sign of risk aversion may

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[2] Note that risk posture with respect to longevity and discounting of future life years are isomorphic (because increasing longevity requires adding years in the future). E.g., if an individual discounts the utility of future life years at rate α (positive or negative) his utility function for longevity exhibits constant absolute risk aversion α, i.e., $u(t) = -sgn(\alpha) \cdot exp(-\alpha t)$. Risk posture with respect to longevity and risk posture with respect to wealth are not necessarily related (Hammitt 2013).

[3] If an individual is risk seeking with respect to wealth over some interval, he should "linearize" the convex section of his utility function by accepting a financial gamble that will shift his wealth outside of this interval; financial gambles that are nearly fair (e.g., roulette wheels) or even more than fair (the stock market) are easily accessible. Fair lotteries on longevity are more difficult to find.

depend on the period (e.g., McNeil et al. 1978 found two respondents were risk-seeking for the first few years and risk-averse for longer periods). In a survey of 10 Harvard health-policy faculty members, Pliskin et al. (1980) found the following frequency of responses to a single question about risk posture with respect to longevity: risk-neutral (4); risk-seeking (4); risk-averse (2). In general-population surveys, Corso and Hammitt (2001) asked respondents to make several choices between paired binary lotteries on length of life. In one survey, 14 percent made risk-averse and 11 percent made risk-seeking choices in all four questions; the remaining 75 percent exhibited no global risk posture (N = 865). In another survey, 13 percent made risk-averse and 9 percent made risk-seeking choices in all five questions; the remaining 78 percent exhibited no global risk posture (N = 610). As described in more detail below, Nielsen et al. (2010) found about half their respondents exhibited no global risk posture; the others were distributed as risk-neutral (6 percent), risk-averse (22 percent), and risk-seeking (23 percent).

Preferences over survival curves

The value of any perturbation to an individual's survival curve can be characterized by its monetary value to the individual (Hammitt 2007). The monetary value may be his compensating variation (i.e., his willingness to pay for the change, WTP) or equivalent variation (i.e., his willingness to accept compensation to forgo the change, WTA).[4] These values depend on the time at which the individual learns of the shift and his ability to adapt his consumption and savings plan to the new conditions. For small perturbations, compensating and equivalent variation are nearly equal in theory, though they may diverge substantially for larger perturbations (Hanemann 1991). For small perturbations, the monetary value can be approximated as minus the present value of the change in mortality hazard function multiplied by the individual's age-dependent marginal rate of substitution between income and mortality risk (VSL), i.e.,

$$W = \int_0^\infty \Delta h(t) v(t) s(t) \rho(t) dt = \int_0^\infty \Delta f(t) v(t) \rho(t) dt, \qquad (5)$$

[4] Note that compensating variation need not be larger for a preferred change to the survival curve although equivalent variation must be. The difference arises because equivalent variation changes income in the baseline scenario while compensating variation changes income in the perturbed scenario and the marginal utility of income may depend on the perturbation.

where $\Delta h(t)$ is the change in hazard, $v(t)$ is minus one times[5] the individual's VSL at date t, and $\rho(t)$ is his consumption-discount factor (Johannesson et al. 1997).

Expression (5) shows that the value of a change in hazard function to an individual depends on the time path of the perturbation, the time path of his VSL (which may depend on health, income, and other factors), and how he discounts future values (e.g., the value of his consumption-discount rate, whether he discounts exponentially or hyperbolically; Frederick et al. 2002). Although it is intuitive that a temporary decrease in the hazard provides greater benefit (in the sense of increasing life expectancy) if it occurs sooner rather than later, an individual may prefer a survival curve with a delayed reduction in the hazard if the product of his VSL, survival probability, and discount factor at the later time is larger than the corresponding product at the earlier time (Hammitt and Liu 2004).

Aversion to financial risk does not enter equation (5) directly, although it may affect VSL. However, the relationship between financial risk aversion and VSL is ambiguous (Eeckhoudt and Hammitt 2004) and so one cannot predict how a difference in financial risk aversion will affect preferences over hazard functions. Financial risk aversion characterizes the difference between the utility-discount and consumption-discount rates, as expressed in the well-known Ramsey rule.[6]

From equation (4), the individual's change in expected utility that results from a change in his probability distribution on time of death $\Delta f(t)$ is equal to

$$\Delta V = \int_0^\infty \Delta f(t) u(t) dt. \qquad (6)$$

Comparing equations (6) and (5) reveals that, viewed from time 0, the (time-dependent) product of the individual's VSL and consumption-discount factor is proportional to his utility for living at *t*. Both functions serve to weight the change in mortality risk as a function of when it occurs. The units are different, however. The weighting factor $v(t) \cdot \rho(t)$ in equation (5) is measured in monetary units (e.g., dollars) and the weighting factor $u(t)$ in equation (6) is measured in utility units.

The proportionality between $u(t)$ and $v(t) \cdot \rho(t)$ reveals an isomorphism between risk posture with respect to longevity and the present value of age-specific VSL. If $v(t)$ is constant

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[5] The negative sign arises because VSL is conventionally defined as the inverse of the rate of substitution between wealth and hazard.

[6] $\mu = \delta + rg$, where μ is the consumption discount rate, δ is the utility discount rate, *g* is the growth rate of consumption, and *r* is the coefficient of relative risk aversion and also the relative degree of aversion to intertemporal equality.

and $\rho(t) = exp(-\alpha t)$ corresponds to exponential discounting at rate α, then $u(t) = -exp(-\alpha t)$, i.e., it exhibits constant absolute risk aversion with absolute risk aversion equal to α. If *v(t)* is constant and $\rho(t) = t^{-\gamma}$ corresponds to hyperbolic discounting, then $u(t) = t^{1-\gamma}/(1-\gamma)$, i.e., it exhibits constant relative risk aversion with parameter γ. Risk neutrality with respect to longevity implies that *v(t)* is inversely proportional to the discount rate; e.g., with exponential discounting at rate μ, *v(t)* increases (in absolute value) at rate μ. Risk-seeking preferences with respect to longevity imply that VSL *v(t)* increases more rapidly than the discount factor $\rho(t)$ decreases.

Empirical evidence on how individuals' VSL varies with *t* is mixed (Hammitt 2007). Standard life-cycle models and some empirical studies suggest VSL rises then falls with age, though the age at which it is maximized and how sharply it rises and falls are uncertain (e.g., Shepard and Zeckhauser 1984, Aldy and Viscusi 2007, 2008, Krupnick 2007). Hence it is uncertain *a priori* what preference ordering over alternative perturbations to his survival curve an individual may hold.

Perturbed survival scenarios

The scenarios we consider are constructed by altering the baseline hazard function (which depends on the respondent's age and gender). Let $h_0(t)$ denote the baseline hazard function for a respondent with *t* measured in years from the present. The three primary scenarios are the proportional, additive, and transient. The hazard functions are:

Proportional: $h_p(t) = h_0(t)\,(1 - p)$ (7a)

Additive: $h_a(t) = h_0(t) - a$ (7b)

Transient: $h_t(t) = h_0(t) - c$ for $0 < t \leq 10$ (7c)

$= h_0(t)$ $t > 10$.

The constant $p = 0.0073$. The constants *a* and *c* depend on the baseline hazard (which varies with the respondent's age and gender) and are determined by the condition that the additive and transient scenarios have the same life expectancy as the proportional scenario.[7] The value of *p* was chosen to balance several criteria, including yielding a

[7] Values of both *c* and *a* increase with respondent age (but decrease as a fraction of current hazard). For a 20-29 year old man (woman) values of *c* and its percentage of baseline hazard are 212e-5, 23 (183e-5, 51). For a 60-69 year old man (woman) they are 500e-5, 3 (443e-5, 5). Values of *a* and percentage of current baseline hazard for a 20-29 year old man (woman) are 62e-5, 7 (51e-5, 14). For a 60-69 year old man (woman) they are 267e-5, 2 (223e-5, 3).

realistically achievable increase in life expectancy and not producing values of *a* or *c* that are large fractions of the baseline hazard for any age group at any age.

We include perturbations of the three primary scenarios by introducing a latency period of 10 or 20 years. For these scenarios, the hazard equals the baseline hazard $h_0(t)$ for $0 < t \leq 10$ (or 20) and takes the form specified above for $t > 10$ (or 20). The value of the parameter corresponding to *p*, *a*, or *c* is determined by the condition that this lagged scenario yield the same life-expectancy gain as the non-lagged version.

For the realistic baseline hazard functions we adopt (which are taken from French life tables[8] and are monotone increasing with age), the primary scenarios can be ordered by the Rothschild and Stiglitz (1970) risk of longevity (see appendix). This implies that all (globally) risk-averse respondents should order the scenarios transient ≻ additive ≻ proportional, all risk-seeking respondents should order the scenarios proportional ≻ additive ≻ transient, and of course all risk-neutral respondents should be strictly indifferent among the scenarios.[9] Similarly, risk-averse respondents should prefer the primary version of a scenario to its lagged version, risk-seeking respondents should have the opposite preference, and risk-neutral respondents should be indifferent between the original and lagged versions.

2. Survey instrument and administration

The survey was administered over the internet to a representative panel of 1246 French residents aged 20-69 years by the CSA survey firm. Data were collected in two waves, a pilot test of 100 respondents (October 2013) and the full implementation of 1146 respondents (November-December 2013). Because there was only one small change to the survey instrument between the pilot and full samples (described below), we pool the samples for analysis.

After eliciting the respondent's age and gender, the survey began with an explanation of life expectancy as the number of additional years one might expect to live, which depend on age and gender, and explained that decreasing mortality risk in any time period would increase life expectancy. Next, the concept of a hazard function was explained

[8] INSEE, Statistiques de l'état civil et estimations de population, Champ : France métropolitaine, territoire au 31 décembre 2009, Tableau 68 - Table de mortalité des années 2007 – 2009, www.insee.fr.

[9] Global risk aversion and global risk seekingness are sufficient but not necessary conditions for these preference orderings.

with a graphic illustrating the chances of survival and death for each future decade for a person of the respondent's age and gender. Age classes are 20-29, 30-39, …, 60-69; we present the hazard for each decade of life beginning with the respondent's next decade (e.g., 30-39 for a respondent aged 20-29). This was followed by an explanation of the three primary risk-reduction scenarios: transient (reducing risk during the next decade, "Program X"), additive (reducing risk in all future decades by subtracting a constant, "Program Y"), and proportional (reducing risk in all future decades by multiplying by a constant, "Program Z"). As noted above, the proportional scenario reduced mortality risk by 0.73 percent in each decade, which yields an increase in life expectancy of between 30 and 37 days (larger for younger respondents who experience the smaller risk beginning at earlier ages). The risk reductions for the additive and transient scenarios depend on age and gender and are selected to yield the same life-expectancy gain as the proportional scenario for that age/gender group. For each of the three scenarios, a graphic provides the baseline, change, and new hazard function and the increase in life expectancy, together with short arguments for and against choosing the scenario (see Figure 1 for an example).

Next, respondents were presented with the three pairwise choices between the scenarios. The choice was presented using a graphic that shows the baseline hazard, the reduction in hazard and final hazard by decade, and the gain in life expectancy for both scenarios (see Figure 2 for an example). The choices were presented so that choosing the first in each pair (or choosing the last in each pair) would yield an intransitive preference order.[10] Respondents who expressed a preference for one of the scenarios were presented with follow-up questions in which the risk reductions by decade and life-expectancy gain of the preferred scenario were sequentially reduced until the respondent indicated that she preferred the other (unaltered) scenario or was indifferent between them; Figure 3 presents the initial follow-up question for a respondent who expressed a preference for the additive over the proportional scenario when the two had equal life-expectancy gains (37 days).

Following the pairwise choices between the transient, additive and proportional scenarios, respondents were presented with a choice between one of the initial scenarios and a latent version of that scenario. In the latent version, there was no risk reduction for the first one or two decades and the risk reduction in the following decades was increased

[10] The pairwise questions were presented as transient vs. additive, additive vs. proportional, and proportional vs. transient.

to yield the same life-expectancy gain as the initial scenario (the initial scenario and latency period were randomized across respondents).

After the preference-elicitation questions, respondents were asked about socioeconomic characteristics (e.g., completed education, household monthly income, number of children and number younger than 18 years). These were followed by questions to elicit financial-risk aversion and consumption-discount rate (explained below), then by qualitative Dospert-scale questions (Blais and Weber 2006) about the perceived riskiness of various activities and how likely the respondent would be to engage in them (e.g., drinking too much at a party, driving a car without fastening the seatbelt, unprotected sex). The survey concluded with questions about health, life expectancy, and overall satisfaction with life (and with various attributes, e.g., family, income), at present and in either 10 or 20 years (using the same period as for the latent risk-reduction scenario and the discounting question). Current health was elicited using the standard categorical scale (excellent, very good, good, fair, poor) and as a numerical value between 0 (equivalent to dead) and 100 (excellent). Perceived life expectancy was elicited as a qualitative response in comparison with others of the same age and gender (much longer, longer, about the same, shorter, much shorter). Current and future life satisfaction were elicited using a 10 point Likert scale.

Financial-risk aversion and time preference were elicited using a format developed by Holt and Laury (2002) for risk aversion and by Coller and Williams (1999) for discount rate. For risk aversion, respondents made 11 choices between a pair of binary lotteries (arrayed as a table), reporting in each row whether they preferred lottery A, B, or were indifferent between them. The monetary amounts varied with stated household income and were more similar in one pair than the other (e.g., for respondents with monthly household income of €4000 to €5000, lottery A offered prizes of €5400 and €3200 while lottery B offered prizes of €9700 and €100). The probability of the larger amount varied from 0 to 1 in steps of 0.1 (the complementary probability of the smaller amount was also displayed).[11] All respondents should choose lottery A in the first row, lottery B in the last row, and should switch from A to B exactly once (possibly choosing indifference for one transitional row).

The questions for time preference were similar in structure. Respondents made 11 choices between receiving a monetary amount in one year or another amount in 11 or 21 years (the time period was matched to the 10 or 20 year version of the latent risk reduction

[11] In contrast, the probabilities in Holt and Laury (2002) start with 0.1.

scenario and the first payment was in one year rather than immediate to limit any effects of present bias). The monetary amounts varied with household income (e.g., the first amount was €27,000 for respondents with income of €4000 to €5000) and respondents were told the annual interest rate associated with each of the delayed payment amounts (rates were 0 through 30 percent). Again, respondents were expected to choose the near-term option when the interest rate was zero and to switch from the near-term to the future payment at most once as the interest rate increases, again possibly reporting indifference for one pair.[12]

3. Results

Table 1 provides descriptive statistics for the sample. Of the 1246 total respondents, 1024 answered all three pairwise choices between risk-reduction scenarios and are retained for analysis. On socio-demographic characteristics, the respondents are representative of the French general population aged 20 to 69 years. Average age is 43.8 years, 53 percent are female, and mean household income net of tax is about €3000 per month. Our sample is better educated than the general population aged 20-69 years (23 percent completed university compared with 16 percent in the general population) and it includes more office workers (31 percent vs. 21 percent) and fewer manual workers (5 vs.17 percent). The shares of other occupations, students, retirees, unemployed and those out of the labor force (e.g., stay-at-home parents) and the distribution by geographic region are within 2 percentage points of the general population. Respondents who did not complete the pairwise choices were on average older (mean 47.7 years) and more likely to be female (63 percent) than those who completed the survey.

On a scale from 0 to 100, respondents' average self-reported health is about 75, consistent with U.S. data (Hanmer et al. 2006). About 24 percent report they expect to live longer than others of their age and gender and 14 percent report they expect to live shorter. On average respondents expect their overall satisfaction with life to decrease over time, with 64 percent reporting they are currently satisfied (i.e., current life satisfaction ≥ 7 on a scale from 1 to 10) and 57 percent reporting they expect to be satisfied in 10 or 20 years (we asked about future life satisfaction for the same period as the latent survival scenarios).

[12] Using monetary amounts to elicit consumption-discount rate is problematic, as respondents can borrow or save at market interest rates and could reasonably accept all rows offering a return greater than the market rate and reject all others.

Pairwise choices

Patterns of choice between paired scenarios are reported in Table 2. The table includes three panels, reporting the responses for each of the pairwise choices. For clarity, Panel A shows the responses to the choice between the transient and additive scenarios. Of the total 1024 respondents, 295 (29 percent) expressed indifference between these scenarios, 448 (44 percent) preferred the additive scenario, and 281 (27 percent) preferred the transient scenario. Of the 448 respondents who preferred the additive scenario when both scenarios offered the same life-expectancy gain, 73 (16 percent) switched to the transient scenario when the life-expectancy gain for the additive scenario was reduced by 8 days, 74 (17 percent) switched when the life-expectancy gain was reduced by 17 days, 103 (23 percent) switched when the life-expectancy gain was reduced by 27 days, and 131 (29 percent) switched when the life-expectancy gain was reduced to zero. Of this last group, 11 respondents switched after initially choosing the scenario with zero life-expectancy gain and receiving a message saying that scenario offered no gain over the baseline.[13] Finally, 67 respondents (15 percent) continued to choose the additive scenario even when the life-expectancy gain was zero. Of these, 10 were in the pilot test (and hence received no message reminding them that the chosen scenarios offered no gain). Panels B and C show results for the other pairwise choices. In all three pairwise choices, about 40 percent of respondents preferred one scenario, 30 percent preferred the other, and 30 percent were indifferent.

Preference orders

Preference rankings over the three primary scenarios, derived from respondents' pairwise choices, are reported in Table 3. Only 155 respondents (15 percent) made pairwise choices that yield an intransitive ranking among the three scenarios. The modal ranking (235 respondents, 23 percent) is indifference among the three scenarios, which is consistent with risk neutrality with respect to longevity. This is followed in frequency by proportional ≻ additive ≻ transient (166 respondents, 16 percent) and the inverse ranking, transient ≻ additive ≻ proportional (146 respondents, 14 percent). These rankings are consistent with globally risk-seeking and risk-averse preferences for longevity, respectively. Combining

[13] The sole difference between the pilot and final surveys was to include this message in the final survey whenever a respondent chose a scenario with no life expectancy gain over one with a positive gain.

these three groups implies that just over half (53 percent) of respondents answered the pairwise choices in a manner consistent with some global risk posture.

The other 322 respondents (31 percent) answered the three pairwise choices in a manner consistent with a transitive ranking, but inconsistent with any global risk posture. The most common of these rankings was additive ≻ proportional ≻ transient, expressed by 131 respondents (13 percent). Note that this ranking is consistent with the modal pairwise choices shown in Table 2, though it is not the modal ranking. Other rankings are much less common, the next most frequent being additive ≻ transient ≻ proportional, exhibited by 71 respondents (7 percent).

Tests for validity of responses

In any stated-preference study, one must consider whether the responses are consistent with thoughtful decision making or may reflect inattention, misunderstanding, hypothetical bias, or other factors. We provide several lines of evidence concerning validity.

A first question is whether the pattern of responses is consistent with random behavior. To evaluate this, note that respondents made three pairwise choices between the primary scenarios and could choose among three response options (first scenario, second scenario, or indifference). In total, 27 preference orderings are possible, of which 13 are transitive. As noted above, the questions were presented so that respondents who followed the easy strategy of always choosing the first alternative (or always the last) would reveal an intransitive preference order. This should bias our results against finding transitive orderings.

If respondents chose randomly among the three response options with equal probability, the expected number of respondents producing transitive orderings would be 13/27 or 48 percent. The probability that the fraction of transitive orderings would be at least as great as the realized fraction (85 percent) is infinitesimally small; the z-statistic to test this hypothesis exceeds 20. Replacing the assumption that the probability of choosing each response option is one-third with the assumption that the probability equals the realized frequency (0.37, 0.34, and 0.29 for first, second, and indifferent, respectively) yields the same conclusion.

Second, for respondents whose preference ordering is consistent with a global risk posture, choices between a lagged version of one of the three primary scenarios and the original scenario are highly consistent with that risk posture. As reported in Table 3, among respondents whose choices among the three primary scenarios were consistent with risk neutrality, nearly all (96 percent) were indifferent between the original and lagged scenario; of those whose choices were consistent with risk seekingness, 81 percent chose the lagged over the original scenario; and of those whose choices were consistent with risk aversion, 77 percent chose the original over the lagged scenario.[14]

Third, the pattern of preference orderings is similar to that obtained by Nielsen et al. (2010). In contrast to our internet survey, in which we have limited ability to motivate respondents, maintain their attention, or clarify any misunderstanding about the questions, Nielsen et al. conducted their survey using methods that should yield greater attentiveness and understanding. They interviewed respondents in-person (in groups of four to ten). In addition, they preceded the elicitation with an incentivized gambling task designed to familiarize respondents with the notion of a survival curve and the concept that winning in one stage provides not only direct benefit but also the possibility of winning in later stages. As shown in Table 3, Neilsen et al. obtained the identical ranking of preference orderings by frequency except many fewer of their respondents than of ours expressed indifference over the three perturbations (6 percent compared with 23 percent). This suggests that respondents who were less thoughtful in completing our survey may have disproportionately reported indifference among the scenarios.

Consistent with this hypothesis, median time to complete the survey is much shorter for respondents who expressed indifference among the three scenarios and somewhat shorter for those whose responses yield an intransitive pattern (as shown in the last column of Table 3).[15] Because respondents who report indifference are not presented with follow-up questions in which the life-expectancy gain from the preferred scenario is sequentially diminished, we expect they will finish more quickly on average. However, the large difference in the median time to complete (8.35 minutes vs. 14.23 minutes for all respondents) suggests many of these respondents rushed through the survey and were presumably less thoughtful about many of their responses.

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[14] Results for the 10 year and 20 year lagged scenarios are similar; these are pooled in Table 3.

[15] Time to complete varies widely across respondents: the 5th, 25th, 75th, and 95th percentiles are 4.85, 9.08, 20.43, and 68.15 minutes, respectively. Respondents were not required to complete the survey in a single session and a few completed it over multiple sessions spanning more than a day.

Financial risk aversion and discount rate

We estimate financial risk aversion and discount rate using two alternative approaches. First, we estimate the two concepts jointly, following Andersen et al. (2008). Second, we elicit the concepts separately for each respondent to obtain values we use in regression equations to explain variation in longevity-risk preferences across individuals.

The joint estimation yields a coefficient of relative risk aversion r = 0.830 (robust standard error = 0.040). This value is slightly larger than Andersen et al.'s estimate for their Danish sample (r = 0.741, standard error = 0.048). One difference is that we estimate r assuming a baseline of zero whereas Andersen et al. assume a baseline of 117 DKK. Our estimated utility-discount rate, δ = 1.25 percent (standard error = 0.32 percent), is much smaller than Andersen et al.'s estimate (δ = 10.1 percent, standard error = 0.8 percent). Several factors may contribute to this difference. First, we elicited discount rates using choices between payment in 1 or in 11 or 21 years while Andersen et al. used choices between payments in 1 or 6 months. For any but the smallest positive interest rates, the difference in payoff between the early and late dates is enormously larger in our survey than in Andersen et al. This effect may be accentuated by the larger amounts at stake in our survey, between €3000 and €50,000 depending on income compared with 3000 DKK (on the order of €500). Additionally, there may be a framing effect because the annual interest rates included in the table of choices presented to respondents are lower in our survey (0 to 30 percent) than in Andersen et al. (0 to 50 percent). Finally, market interest rates, which may provide a reference level to respondents, were smaller at the time of our survey (autumn 2013) than that of Andersen et al. (June 2003).

We estimate respondent-specific values separately, because joint estimation does not converge for all individuals. We estimate individual values only for respondents who answered the financial risk aversion or discount rate questions in a logical manner, i.e. switched from the lower to the higher risk gamble, or from the early to the late payment, at most once as the probability of the larger payment or the discount rate increased. The individual value is estimated as the midpoint between the values that yield indifference in the rows immediately before and after the individual switched (or the value that yields indifference for the row in which he reported indifference).

As shown in Table 1, the sample mean coefficient of relative risk aversion *r* = 0.46. About 16 percent of respondents are approximately risk neutral, 84 percent are risk averse and 16 percent are risk seeking with respect to money.[16]

The sample-mean consumption-discount rate μ = 11.81 percent per year, substantially larger than the utility-discount rate estimated above (1.25 percent). Equal fractions of respondents (12 percent) always chose the delayed payment (μ < 1 percent) or payment in one year (μ > 30 percent). The median discount rate is about 5 percent and 85 percent exhibit rates less than 20 percent.

Preference orders and individual characteristics

To identify whether preference rankings can be predicted from respondent characteristics, we estimated multinomial-logit models. Table 4 reports estimates of a model where the omitted category is strict indifference. As shown in the table, older respondents tend to be less likely to prefer either of the rankings for which the transient risk reduction is ranked last, which is consistent with a plausible interest in not postponing risk reduction. Similarly, respondents with a larger discount rate are less likely to choose rankings in which the transient scenario is last.

Larger household income is strongly associated with choosing almost any preference ordering except strict indifference. The largest estimated coefficient is for the risk-seeking preference ordering, but the coefficients for the risk-averse and the additive ≻ proportional ≻ transitive scenario are nearly as large. Completing university education is associated with a preference for the risk-averse and other-transitive orderings. Perceived life expectancy (compared with others of the same age and gender) and current and future life satisfaction show little effect, although a few of the estimated coefficients are significantly different from zero.

We tested other variables for inclusion in the regression, including estimated financial risk aversion, gender, number of children in the household, current health, and the Dospert-scale measures of general risk-taking behavior. These variables showed no significant effects.

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[16] The respondents classified as approximately risk neutral switched from the safer to the riskier lottery at the row consistent with risk neutrality. *r* > 1 for 28 percent and *r* < -1 for 2 percent of respondents.

Intensity of risk preference

As summarized in Table 3, slightly more than half the respondents made choices consistent with a global risk posture with respect to longevity. Of these, 235 were risk-neutral, 166 risk-seeking, and 146 risk-averse. We examine the extent to which these choices are consistent with a CRRA utility function, $u(t) = t^{1-\gamma}/(1-\gamma)$, or a CARA utility function, $u(t) = -exp(-\alpha t)$, where γ and α are the (respondent-specific) coefficients of relative and absolute risk aversion with respect to longevity, respectively.

Each respondent's degree of risk aversion can be estimated from the questions in which the life-expectancy gain of the preferred scenario was decreased until the respondent switched to the other scenario (Table 2). For the 235 respondents whose choices were consistent with risk neutrality, $\gamma = \alpha = 0$. For the others, the point at which they switch from one scenario to the other as the life-expectancy gain of the preferred scenarios is decreased provides a bound on the degree of risk aversion. For example, if a female respondent aged 20-29 years chooses the proportional over the additive scenario when the two have equal life expectancies, maintains that choice when the life-expectancy gain of the proportional scenarios is decreased by 8 days, but switches to the additive scenario with the gain is reduced by 17 days, her (risk-seeking) choices are consistent with a CRRA utility function with γ between -0.79 and -2.47 and a CARA utility function with α between -0.02 and -0.05. For each respondent, we obtain three intervals from the three sets of pairwise choices and classify an individual's choices as consistent with a CRRA or CARA utility function if and only if these three intervals intersect. For respondents who are not risk neutral, the degree of risk aversion is bounded by the intersection of these intervals; we estimate regression models using maximum-likelihood methods assuming a normal error term.

Of the 146 respondents whose choices are consistent with global risk aversion, only 60 made all three pairwise choices consistent with a CRRA utility function and 57 made choices consistent with a CARA function. Similarly, of the 166 respondents whose choices are consistent with global risk seekingness, 63 made choices consistent with a CRRA utility function and 47 made choices consistent with CARA utility.[17]

Table 5 reports regression models that describe how the estimated values of γ and α vary among the respondents whose pairwise choices are consistent with CRRA or CARA

[17] Respondents whose choices are consistent with CARA utility are not a perfect subset of those whose choices are consistent with CRRA utility.

utility functions. Overall, younger and higher-income respondents are less averse to longevity risk. We find few significant associations with other variables, including education, number of children in the household, future life satisfaction, or consumption-discount rate.

4. Conclusions

Overall, we find that respondents to an internet survey are able to answer questions asking them to choose between alternative perturbations of a baseline survival curve yielding a life-expectancy gain of about one month with a substantial degree of coherence. For the three pairwise choices, 85 percent provide answers yielding a transitive preference ordering. The probability of obtaining such a large fraction of transitive orderings if responses were simply random is negligibly small. Moreover, of the 53 percent of respondents whose pairwise choices imply some global risk posture with respect to longevity (risk neutrality, risk aversion, or risk seekingness), 87 percent answer the question choosing between one of these scenarios and a lagged version consistently with that global risk posture.

We find a high degree of heterogeneity among individuals' preference orderings, but this heterogeneity is not well-explained by available socio-demographic characteristics, preference characteristics such as discount rate and financial risk aversion, or other variables such as judgments about current and future life satisfaction or general risk perceptions and risk-taking behavior. We find that older respondents and those who express higher consumption-discount rates are less likely to choose preference orders in which the transient risk reduction is ranked last, consistent with an interest in not delaying risk reduction. Higher-income respondents are less likely than others to express indifference or risk neutrality across scenarios. Similarly, among respondents whose choices are consistent with a CRRA or CARA utility function, older respondents are more risk-averse and higher-income respondents are less risk-averse than others.

Direct choice between alternative survival curves provides information about preferences over longevity risk that complements the information provided by studies of how VSL varies with age (e.g., Shepard and Zeckhauser 1984, Aldy and Viscusi 2007, 2008, Krupnick 2007). As described above, the utility function for longevity is proportional to the product of the individual's consumption-discount factor and age-specific VSL, i.e., the present value of future VSL. Risk aversion with respect to longevity implies that the present value of future VSL decreases with t, i.e., if VSL increases, it grows more slowly than the discount rate. Conversely, risk seeking preferences toward longevity imply the VSL increases more quickly than the discount rate. Risk neutrality implies the VSL grows at exactly the discount rate. The substantial share of respondents whose preference orderings are consistent with global risk neutrality or risk seekingness toward longevity (39 percent) suggests that patterns of increasing VSL over a substantial age range may be common in the population, and hence the notion that VSL is proportional to remaining life expectancy (equivalently, that the value per statistical life year, VSLY, is independent of age) is not accurate for many individuals.

In summary, these results suggest that there is substantial heterogeneity in preferences over time paths of mortality-risk reduction. Conventional measures of the benefit of mortality-risk reduction such as life years or quality-adjusted life years gained, or a value per statistical life with a fixed pattern of age-dependence (including constant), are not likely to provide accurate measures of the value of life-saving interventions to most individuals.

Appendix

The three primary scenarios are ordered by the Rothschild and Stiglitz (1970) risk of longevity; the proportional scenario is riskier than the additive scenario which is riskier than the transient scenario. In addition, the lagged version of each of these scenarios is riskier than the original version.

To see this, recall that Rothschild and Stiglitz (1970) define a lottery R as riskier than a lottery Q, having the same mean, if lottery Q second-order stochastically dominates R, i.e., satisfies the integral condition

$$\int_{-\infty}^{t} F_Q(\mu)d\mu \leq \int_{-\infty}^{t} F_R(\mu)d\mu \tag{A.1}$$

$\forall t$, where F_i is the distribution function for lottery *i*. Because the survival function $s(t) = 1 - F(t)$ (see equation (1)) and is defined only for non-negative t, the integral condition (A.1) is equivalent to

$$\int_{0}^{t} s_Q(\mu)d\mu \geq \int_{0}^{t} s_R(\mu)d\mu \tag{A.2}$$

$\forall t \geq 0$. The survival function can be expressed as a function of the hazard,

$$s(t) = exp\left[-\int_{0}^{t} h(\mu)d\mu\right]. \tag{A.3}$$

Substituting (A.3) into (A.2) yields

$$\int_{0}^{t} exp\left[-\int_{0}^{\mu} h_Q(\tau)d\tau\right]d\mu \geq \int_{0}^{t} exp\left[-\int_{0}^{\mu} h_R(\tau)d\tau\right]d\mu. \tag{A.4}$$

Because our scenarios have equal life expectancy, expression (A.4) is satisfied with equality in the limit as $t \to \infty$. To show that scenario R is riskier than scenario Q, it suffices to show that (A.4) is satisfied as an inequality for $0 < t < \infty$. For our scenarios, we can show that there exists a value t* such that $h_Q(t^*) = h_R(t^*)$, for $0 < t < t^*$, $h_Q(t) < h_R(t)$, and for $t > t^*$, $h_Q(t) > h_R(t)$. Hence expression (A.4) is satisfied.

Recall the baseline hazard $h_0(t)$ is monotone increasing in *t* for all age/gender groups in our survey. Because the scenarios have equal life expectancy, the parameters of the hazard functions (defined in expressions (7a) – (7c)) satisfy $c > a > p$. Moreover, values of the parameters of the lagged scenarios corresponding to *c*, *a*, and p are each respectively larger than the corresponding parameters in the original scenarios. Hence, for small *t*, $h_T(t) < h_A(t) < h_P(t)$ and $h_i(t) < h_{Lj}(t)$ where h_{iL} is the hazard for the lagged version of scenario *i*. For large t, each of these inequalities is reversed, and for some t* (depending on the scenarios), each of these inequalities is an equality. Substituting these hazard functions into expression (A.4) proves the result.

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References

Aldy, J.E., and W.K. Viscusi, "Age Differences in the Value of Statistical Life: Revealed Preference Evidence," *Review of Environmental Economics and Policy* 1, 241-260, 2007.

Aldy, J.E., and W.K. Viscusi, "Adjusting the Value of a Statistical Life for Age and Cohort Effects," *Review of Economics and Statistics* 90, 573-581, 2008.

Andersen, S., G.W. Harrison, M.I. Lau, and E.E. Rutström, "Eliciting Risk and Time Preferences," *Econometrica* 76, 583-618, 2008.

Blais, A.R. and E.U. Weber, "A Domain-Specific Risk-Taking (DOSPERT) Scale for Adult Populations," *Judgment and Decision Making* 1(1), 33-47, 2006.

Carthy, T., S. Chilton, J. Covey, L. Hopkins, M. Jones-Lee, G. Loomes, N. Pidgeon, and A. Spencer, "On the Contingent Valuation of Safety and the Safety of Contingent Valuation: Part 2 – The CV/SG 'Chained' Approach," *Journal of Risk and Uncertainty* 17, 187-213, 1999.

Chilton, S., M. Jones-Lee, F. Kiraly, H. Metcalf, and W. Pang, "Dread Risks," *Journal of Risk and Uncertainty* 33, 165-182, 2006.

Coller, M., and M.B. Williams, "Eliciting Individual Discount Rates," *Experimental Economics* 2, 107-127, 1999.

Corso, P.S., and J.K. Hammitt, "Preferences for Longevity Risks: Effects of Lottery and Personal Characteristics," Harvard Center for Risk Analysis, December 2001.

Drèze, J., "L'Utilitè Sociale d'une Vie Humaine," *Revue Française de Recherche Opèrationelle* 6, 93-118, 1962.

Eeckhoudt, L., and J.K. Hammitt, "Does Risk Aversion Increase the Value of Mortality Risk?" *Journal of Environmental Economics and Management* 47, 13-29, 2004.

Frederick, S., G. Loweinstein, and T. O'Donohue, "Time Discounting and Time Preference: A Critical Review," *Journal of Economic Literature* 40, 351-401, 2002.

Hammitt, J.K., "Valuing Mortality Risk: Theory and Practice," *Environmental Science and Technology* 34, 1396-1400, 2000.

Hammitt, J.K., "QALYs versus WTP," *Risk Analysis* 22, 985-1001, 2002.

Hammitt, J.K., "Valuing Changes in Mortality Risk: Lives Saved vs. Life Years Saved," *Review of Environmental Economics and Policy* 1, 228-240, 2007.

Hammitt, J.K., "Admissible Utility Functions for Health, Longevity, and Wealth: Integrating Monetary and Life-Year Measures," *Journal of Risk and Uncertainty* 47, 311–325, 2013.

Hammitt, J.K., and J.-T. Liu, "Effects of Disease Type and Latency on the Value of Mortality Risk," *Journal of Risk and Uncertainty* 28, 73-95, 2004.

Hanemann, W.M., "Willingness to Pay and Willingness to Accept: How Much Can They Differ?" *American Economic Review* 81, 635-647, 1991.

Hanmer, J. W.F. Lawrence, J.P. Anderson, R.M. Kaplan, and D.G. Fryback, "Report of Nationally Representative Values for the Noninstitutionalized US Adult Population for 7 Health-Related Quality-of-Life Scores," *Medical Decision Making* 26, 391-400, 2006.

Holt, C.A., and S.K. Laury, "Risk Aversion and Incentive Effects," *American Economic Review* 92, 1644-1655, 2002.

Johannesson, M., P.-O. Johansson, and K.-G. Lofgren., "On the Value of Changes in Life Expectancy: Blips Versus Parametric Changes," *Journal of Risk and Uncertainty* 15, 221-239, 1997.

Jones-Lee, M.W., "The Value of Changes in the Probability of Death or Injury," *Journal of Political Economy* 82, 835-849, 1974.

Krupnick, A., “Mortality-risk Valuation and Age: Stated-Preference Evidence,” *Review of Environmental Economics and Policy* 1, 261-282, 2007.

Magat, W.A., W.K. Viscusi, and J. Huber, “A Reference Lottery Metric for Valuing Health,” *Management Science* 42, 1118-1130, 1996.

McNeil, B.J., R. Weichselbaum, S.J. Pauker, “Fallacy of the Five-Year Survival in Lung Cancer,” *New England Journal of Medicine* 299, 1387-1401, 1978.

Menezes, C., C. Geiss, and J. Tressler, “Increasing Downside Risk,” *American Economic Review* 70, 921–932, 1980.

Nielsen, J.S., S. Chilton, M. Jones-Lee, and H. Metcalf, “How Would You Like Your Gain in Life Expectancy to be Provided? An Experimental Approach,” *Journal of Risk and Uncertainty* 41, 195–218, 2010.

Pliskin, J.S., D.S. Shepard, and M.C. Weinstein, “Utility Functions for Life Years and Health Status,” *Operations Research* 28, 206-224, 1980.

Rosen, S. “The Value of Changes in Life Expectancy,” *Journal of Risk and Uncertainty* 1, 285-304, 1988.

Rothschild, M., and J. Stiglitz, “Increasing Risk: I. A Definition,” *Journal of Economic Theory* 2, 225-243, 1970.

Shepard, D.S., and R.J. Zeckhauser, “Survival versus Consumption,” *Management Science* 30, 423-439, 1984.

Van Houtven, G., M.B. Sullivan, and C. Dockins, “Cancer Premiums and Latency Effects: A Risk Tradeoff Approach for Valuing Reductions in Fatal Cancer Risks,” *Journal of Risk and Uncertainty* 36, 179-199, 2006.

Viscusi, W.K., W.A. Magat, W.A., and J. Huber, “Pricing Environmental Health Risks: Survey Assessment of Risk-Risk and Risk-Dollar Tradeoffs for Chronic Bronchitis,” *Journal of Environmental Economics and Management* 21, 32-51, 1991.

Wright, J.C., and M.C. Weinstein, “Gains in Life Expectancy from Medical Interventions – Standardizing Data on Outcomes,” *New England Journal of Medicine* 399, 380-286, 1998.