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Expectations, Aging and Cognitive Decline*

Gábor Kézdi[a] and Robert J. Willis[b]

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Abstract

Expectations play an important role in decisions under uncertainty. Yet we have limited empirical knowledge about how expectations are formed, how they change, and how they affect behavior, especially in the population in general. In particular, we know little about whether and how aging affects expectations or what the consequences may be for important decisions. In this paper, we use longitudinal data from the HRS to document general patterns in expectations in various domains with respect to aging and investigate the potential role of cognitive decline in those patterns. We focus on two aspects of expectations: optimism and uncertainty. With the notable exception of survival expectations, we find that optimism decreases and uncertainty increases with age in five different domains, controlling for time, cohort and selection effects and that cognitive decline plays a modest but statistically significant role in explaining the decline of optimism and a less significant role in accounting for the increase of uncertainty. In contrast, optimism about survival chances increases significantly with age and uncertainty decreases. We speculate that increased optimism about survival is consistent with Carstensen's socioemotional selectivity theory of aging and that such expectations may also serve as a heuristic in choosing sufficient precautionary resources in the face of an uncertain lifetime

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[a]Central European University and IEHAS. kezdig@ceu.hu
[b]University of Michigan and NBER. rjwillis@umich.edu

Expectations play an important role in decisions under uncertainty. Yet we have limited empirical knowledge about how expectations are formed, how they change, and how they affect behavior, especially in the population in general (see Hurd, 2009 for a review of the empirical literature). In particular, we know little about whether and how aging affects expectations. If aging has direct effects on the way people form expectations those effects may have consequences for the quality of important decisions.

In this paper we use data from the Health and Retirement Study (HRS) to document general patterns in expectations in various domains with respect to aging and investigate the potential role of cognitive decline in those patterns. We focus on two aspects of expectations: optimism and uncertainty. We define optimism as higher probabilities put on events that have positive consequences. We define uncertainty as people's inability or unwillingness to state a probability belief or evidence of ambiguity or vagness in the beliefs that they do report. (Hudomiet and Willis, 2012, use a similar concept of uncertainty but follow a different measurement strategy). Both optimism and uncertainty should be important for decisions: by shifting the level of expectations, optimism can have direct effects, while uncertainty can affect decisions in interaction with risk aversion or more subtle preferences such as ambiguity aversion or loss aversion.

Although both optimism and uncertainty can be specific to the events in question, we show empirically that aging may have general effects on both. Aging appears to make expectations less optimistic and more uncertain in general. These effects are not universal but correspond to general events that are beyond the control of the individuals.

There are several possible reasons that aging might have these general effects. A leading possibility is that cognitive decline associated with aging affects an individual's view of the world and ability to process information about it, causing a person to overstate the likelihood of negative events and to hold less precise probabilistic beliefs. Another possibility is that the increase in the force of mortality that accompanies aging leads to decreased attention to events that are far in the future, thus reducing incentives to acquire knowledge about such events.[1]

Relatedly, from a psychological point of view, Carstensen (2006) theorizes that that aging makes people focus less on long-run goals and more on near term emotional sources of satisfaction. These economic and psychological influences on time perspective suggest that aging may lead to reduced attention to macroeconomic events. Finally, as the economic situation of a household shifts from work to retirement and from the accumulation of wealth to managing it during retirement, the relevance of particular kinds of economic events may diminish or increase.

Since little is known about the effect of aging on optimism or uncertainty of expectations, our major aim in this paper is to provide descriptive evidenceusing longitudinal data from the HRS without imposing much theoretical structure or seeking causal results. We do, however, pay close attention to

[11] See Kézdi and Willis, 2011, for a model showing how expectations about stock market returns are affected by incentives to learn about the history of returns and other aspects of financial investment and that more optimistic expectations are associated with greater participation in stock ownership.

methodological issues involving measurement error, cohort differences and mortality selection in order to avoid findings that are statistical artifacts rather than patterns associated with aging. Our treatment of mortality selection builds on the approach of Agarwal, Discoll, Gabaix and Laibson (2009) who argue that aging leads to an increase in "mistakes" in decision making which may be a consequence of cognitive decline. From a substantive point of view, our examination of changes in optimism and uncertainty with aging and the relationship of these changes to cognitive decline is complementary to their analysis.

We begin our analysis by deriving simple measures of optimism and uncertainty about particular topics from HRS questions about subjective probability beliefs about survival, one's own future income growth, the chance of a future economic depression, one year ahead stock market returns, job loss and whether tomorrow will be a sunny day.[2] Next, we show how these measures change with aging, employing methods to isolate "pure" age effects by eliminating cohort and time effects. We then turn our attention to measures of cognition from the HRS and describe the process of cognitive decline with age. Finally, we examine how changes in optimism and uncertainty in each domain is related to cognitive decline.

Data

We use data from seven waves of the Health and Retirement Study (HRS), 1998 to 2010. The HRS started in 1992 with a cohort of individuals of age 51 to 61 and their spouses. In 1998, the sample was refreshed to be representative of all age groups above 50 years of age. The spouses of all respondents are also interviewed, regardless of their age. The sample has been refreshed by a new six-year cohort of 51-56 year olds and their spouses every six years (in 2004 and 2010). 2010 is the last wave with available data. We use data on all individuals that were interviewed in at least two survey waves and were 51 to 90 years old at the time of the interview. Proxy interviews are discarded because they lack observations on expectations. Altogether, our analysis uses 107,024 observations on 20,938 individuals.

The HRS has asked questions about probability beliefs in various dimensions from its beginnings in 1992. This analysis focuses on the six questions summarized in table 1 below.

Table 1. The expectation questions of the HRS used in the analysis

Question label	Exact wording of the question
survival to age A	What is the percent chance that you will live to be A or more? (threshold A being a function of the age of the respondent)
sunny day	What do you think are the chances that it will be sunny tomorrow?
income growth	What do you think are the chances that your income will keep up with inflation

[2] The sunny day question in HRS has been used as a measure of optimism by Basset and Lumsdaine (1999).

	for the next five years?
job loss	What are the chances that you will lose your job during the next year?
stock market	By next year at this time, what is the percent chance that mutual fund shares invested in blue chip stocks like those in the Dow Jones Industrial Average will be worth more than they are today?
economic depression	What do you think are the chances that the U.S. economy will experience a major depression sometime during the next 10 years or so?

Respondents were invited to answer these expectations questions in percentage terms. The question sequence is introduced by explaining the task and giving an example of the chances of rain on the day following the interview. In some survey waves, the sunny day question was then used as a warm-up question. Not every question was asked in every wave of the HRS: of the six questions we analyze, only the survival question was asked every time. We display the number of individuals in our sample that were asked each question in each survey wave in table 2 below. Not every expectation question is asked of everyone, but five of the six questions we analyze were asked of all participants in at least some of the survey waves (the exception is the job loss question that was restricted to those who were employed). Besides general availability, the main motivation behind selecting the six questions above is the fact that it is relatively straightforward to assign positive or negative meaning to them, which is important in our analysis of optimism.

We analyze two aspects of expectations: optimism and uncertainty. We define optimism as higher probabilities put on events that have positive consequences. Operationalizing this definition is relatively straightforward for the probability answers we examine: the measure of optimism is the probability answer itself. We re-defined answers to the economic depression and the job loss questions by subtracting them from 100 percent so that they, too, correspond to positive events. In order to adjust for potential age-related trends in the underlying "true" probabilities, we made two additional adjustments. First, we discarded the sunny day answers of respondents that moved to another location since their previous interview. This way we can make sure that age-related changes of residence (e.g., to retirement communities in southern states) do not affect our measure of sunshine optimism. Changes in season are controlled by dummy variables for month of interview. Second, we replaced the answer to the question of survival to age A with the difference of the answer from the corresponding probability implied by life tables.[3]

Conceptually, we define uncertainty as a person's inability to form a probabilistic belief or his admission that his beliefs are imprecise. For each expectation question, we measure uncertainty by the propensity to answer "don't know" or "50 percent." "Don't know" clearly signals inability to form

[3] These implied survival probabilities were compiled from the appropriate life table for each gender, year of age and year o survey observation. The variable is part of the RAND distribution of the HRS as the ratio of answers to the survival probability questions to the probabilities implied by the life tables. We transformed that variable to measure the difference instead of the ration. The RAND documentation is available at http://www.rand.org/content/dam/rand/www/external/labor/aging/dataprod/randhrsL.pdf, pages 1019-1025.

probabilistic expectations. The similar interpretation of the 50 percent answers is motivated by an assumption that most respondents mean “unsure” when they say “50 percent.” This assumption is supported by evidence. Starting with 2006, the HRS asked a follow-up question to people who answered “50 percent” to the stock market question and the survival expectation question. For example, among respondents who answered “50” to the stock market question, a follow-up question asked whether they thought it was equally likely that the market would go up or go down or whether they were “just unsure.” Seventy per cent of the respondents said unsure for both the stock market and the survival question. Our results are qualitatively the same if we exclude the 50 percent answers and measure uncertainty by the propensity to give a “don’t know” answer only.

Besides establishing the effects of aging, our analysis aims to uncover whether those effects are related to the decline of cognitive functioning. Cognitive functioning is measured by a composite 27-point variable that combines results from four short cognitive tests that were administered in each wave of the HRS we use. These four tests were the two word recall test, a backward counting test and the “serial sevens” test. The first tests ask respondents to recall 10 words immediately after hearing them from the interviewer, within one minute, while the second tests asks for the same task some time later after having answered other survey questions. The score from these two tests is the number of correctly recalled words. The third test asks respondents to count backward from 20, and the score is 1 if the answer is correct. The fourth test asks respondents to subtract 7 from 100, then subtract 7 from the result, and so forth., up until 6 subtractions. The score from this test is the number of correct subtractions. The combined score we use is standard in the literature that investigates cognitive functioning using HRS data.[4]

In some of our analysis we examine the association with normal cognitive aging as distinguished from associations with the onset of dementia. Dementia is a loss of cognitive functioning beyond “normal aging.” Dementia may cause people to be unable to answer complex survey questions such as the expectations questions. Most severely demented respondents participate in the HRS via proxy interviews, and such respondents are not asked to answer the cognitive tests and the expectation questions. As a result, it is not possible to analyze the associations of dementia with expectations in our data in a direct fashion. At the same time, signs of the onset of dementia can be detected in our sample using the prediction model developed by Hurd, Martorell, Delavande, Mullen and Langa (2013). Using a clinical diagnosis of dementia in the ADAMS study of a subset of HRS respondents (Plassman, et al., 2007), Hurd et al. (2013) assigned predicted probabilities for dementia status one year after the interview for every respondent in the HRS. These predictions use variables observed in the HRS and combine those variables into probabilities using an ordered probit model with three outcomes (dementia, severe impairment without dementia and normal aging). For non-proxy interviews the variables used in the prediction are the cognitive score, the change of the cognitive score from the previous interview, demographic characteristics and measures of assistance with activities of daily living (ADL). Because of mechanical correspondence to the cognitive score variable, joint analysis of

[4] A fifth measure is often added to the score to control for dementia (Crimmins, Kim, Langa and Weir, 2011), but we use a different, more reliable measure of dementia and do not include that score in our cognitive measure. The HRS cognitive measures are described in more detail in Fisher, et al. (2012).

the decline in the cognitive score and the predicted probability of dementia would be problematic. As we shall see, the predicted probability is practically zero below age 70, which further limits the scope for joint analysis. Instead, we use the predicted probability of dementia in our robustness checks to see if associations with cognitive decline correspond to normal aging or early signs of dementia.

Table 2. Number of observations for the expectation questions and the cognitive measures, by survey wave

	HRS survey wave						
question label	1998	2000	2002	2004	2006	2008	2010
survival to age A	7,169	13,894	14,807	15,899	15,241	15,040	13,432
sunny day	0	14,792	15,451	16,867	0	0	0
income growth	14,591	14,792	15,451	16,867	16,266	0	0
job loss	4,847	4,506	3,943	4,925	4,393	0	3,192
stock market	0	0	13,412	16,647	15,874	15,045	13,491
economic depression	3,400	108	149	16,647	15,874	15,045	0
cognitive score	14,591	14,792	15,463	16,912	16,280	15358	13,628
Probability of dementia	0	4,299	5,005	5,320	5,572	5,802	5,662

Source: HRS waves 1998 through 2010. Sample: respondents of 51 through 90 years of age, without the new respondents in 2010 and without the proxy interviews. Number of observations refers to the number of individuals in the sample that were asked the relevant question (including individuals that refused to answer or gave don't know answers).

The income growth question was discontinued in 2008. The economic depression question was discontinued in 2010, and prior to 2004, it was asked from new respondents only (new spouses and the new cohort in 1998). The stock market question was asked first in 2002. The job loss question was asked in all waves except for 2008, but only from a subset of the respondents who were employed at the time of the interview.

Expectations and aging

The effect of aging on expectations is difficult to measure for many reasons. Cross-sectional age profiles blend the effect of aging with differences across birth cohort and selective mortality. Cohort differences may lead to cross-sectional age differences in expectations if older birth cohorts have different expectations than the younger birth cohorts, even if we compared them when they were at the same age. Selective mortality may lead to cross-sectional age differences in expectations if mortality is correlated with expectations (perhaps due to common factors). Nevertheless, we show the cross-sectional age profiles of average optimism and uncertainty for reference.

Examining changes of expectations for the same people eliminates the confounding cohort effects. One can build up age profiles from the individual changes by creating aggregate slopes and cumulating those slopes (this method was used by Agarwal, Driscoll, Gabaix and Laibson, 2009). The slopes of average measures is defined as

$$s(x)_a = \frac{1}{N_{\Omega(a)}} \sum_{i \in \Omega(a)} \frac{x_{i,w+1} - x_{i,w}}{age_{i,w+1} - age_{i,w}} \quad (1)$$

where x is the relevant variable, $s(x)_a$ is the slope starting with integer age a, i refers to individuals, w refers to the survey wave, *age* in the denominator is measured in fine detail (in 1/12th years, calculated from the month of birth of the individual and the month of the interview), and $\Omega(a)$ refers to the set of individuals that belong to an age group defined by integer age a. Having the slopes estimated, one can add them up from a pre-specified starting value and create age profiles that are identified from wave-to-wave changes.

However, wave-to-wave changes blend the effects of aging with the effects of calendar time. Calendar time may affect expectations about most of our measures, including income growth, economic depression, the stock market going up or a sunny day.

Fortunately, the features of the data collection help us to control for calendar time effects. The data collection of any survey is spread out over time. In a typical HRS wave, over 80 per cent of the interviews are completed within 6 months, and the remaining interviews take another 5 to 8 months to collect. This induces variation in the time that passes between two interviews for different individuals. Measured to monthly precision, the median amount of time between two interviews is exactly 2 years, the 1st decile is 1 and 9/12 years, the 9th decile is 2 and 6/12 years, and the tails are long. As a result, the wave-to-wave difference in any measure may correspond to different age differences for different individuals.

We control for calendar time effects by replacing each expectation variable with its deviation from the mean measured in the year-month of the interview. That is., we replace variable x in equation (1) by the following variable:

$$\tilde{x}_{iw} = x_{iw} - \frac{1}{n_m} \sum_{j \in \Omega(m)} x_{jw} \qquad (2)$$

where m refers to the year-month of the interview, and $\Omega(m)$ refers to the set of all observations in our sample in year-month m. Identifying the age slopes from the year-month adjusted variables uses the assumption that calendar time has a level effect that is equal across all respondents.[5] Under that

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[5] The age slopes of the year-month adjusted variables are identified from differences-in-differences-in-differences. Consider two respondents of exactly the same age interviewed in the same month in the base wave. One of them is interviewed in exactly 2 years in the following wave, by which time her age also increased by 2 years. The other respondent is interviewed six months later so that his age increased by 2.5 years. The difference in the change of their outcomes may reflect differences in aging and also differences in the calendar time of the second wave. If we assume that the differences induced by the difference in calendar time are the same for all respondents, we can estimate that using pairs of respondents who have the same calendar time difference between their second interview, but the time elapsed from their base interview is the same (say, 2 years for

assumption, the age profiles built up using age slopes of the year-month adjusted variables $s(\tilde{x})_a$ show the effects of age without cohort effects and without calendar time effects.

Age Profiles of Optimism. We first show the age profiles of optimism by displaying the level of expectations as a function of age. Recall that we adjusted some of the expectation variables to reflect cleaner measures of optimism than the original answers. First, we flipped the answers to the economic depression and the job loss questions so that higher values reflect more optimistic expectations. Second, we discarded the sunny day answers of respondents who moved to another location since their previous interview. Third, we replaced the answer to the question about survival to age A with the difference between the survey answer and the corresponding probability implied by life tables. All answers were replaced by their deviations from their year-month average.

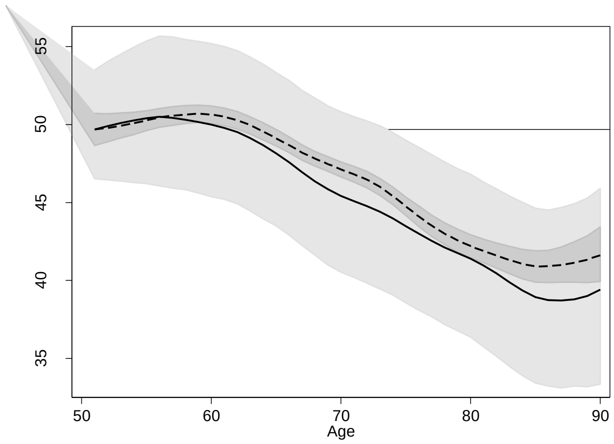
Figure 1 shows the results. In each graph, the dashed line shows the cross-sectional age profile of the original answers, while the solid line shows the age profile built up by the cumulative slopes of the year-month adjusted answers. The figures show the bootstrap 95 percent confidence intervals around the curves, colored as lighter gray for the cumulative slopes and darker gray for the cross-sectional profiles.[6] With the exception of the survival probability answers (more about them later), the cross-sectional age profiles blend cohort, time, and selection effects with age effects, while the age profiles from the cumulative year-month adjusted slopes show pure age effects. Each graph shows a horizontal line at the level of the optimism measure at age 51, the normalized starting point for the age profiles.

The effect of age on optimism is negative in five of the six cases, and it is statistically significant in the case of stock market, sunshine and real income growth expectations. While one can construct specific explanations for some of the figures (aging may lead to lower real incomes), such explanations are harder to construct for other figures (the stock market or the sunny day). It appears therefore that there may be a negative effect of age on optimism in general in the kinds of domains represented by the three figures.

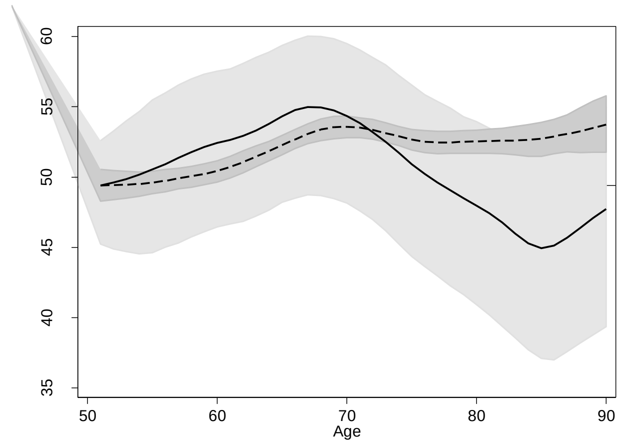
One can think of the solid-line profiles, based on cumulative slopes, as robustness checks to the dashed cross-sectional profiles which remove the potential effects of birth cohort and selection. With the exception of survival expectations, the solid lines are not statistically significantly different from the dashed ones. Most importantly, whenever the dashed cross-sectional age profiles are negative, the solid profiles are also significant and negative. Although not statistically significant, the divergence between the cross-sectional profiles from the cleaner age profiles of job loss expectations is consistent with

both). If there is a difference in this second comparison, we record that and subtract from the difference measured in the first comparison.

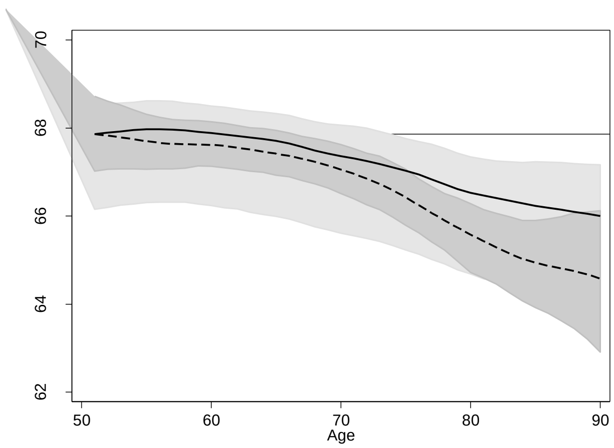
[6] The boostrap procedure involved drawing entire histories of answers of households (spouses together) and repeating the all the estimation procedures within each bootstrap draw. We expect confidence intervals to be wider for the profiles of cumulative age-adjusted differences because the role of measurement error and other time-varying idiosyncratic variation in the answers get magnified by taking differences.



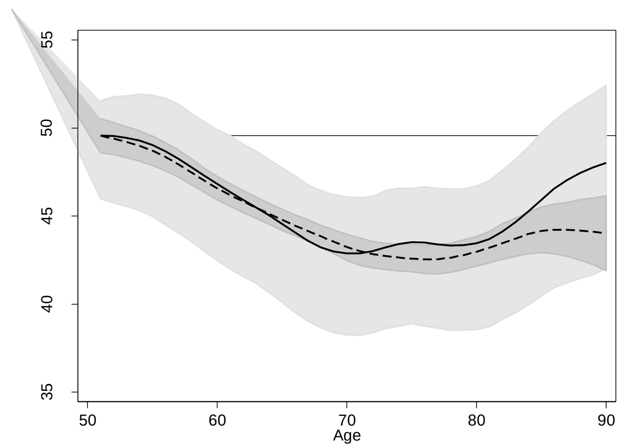
a.The stock market will go up
- - - cross-sectional profile; ─── cumulative slopes



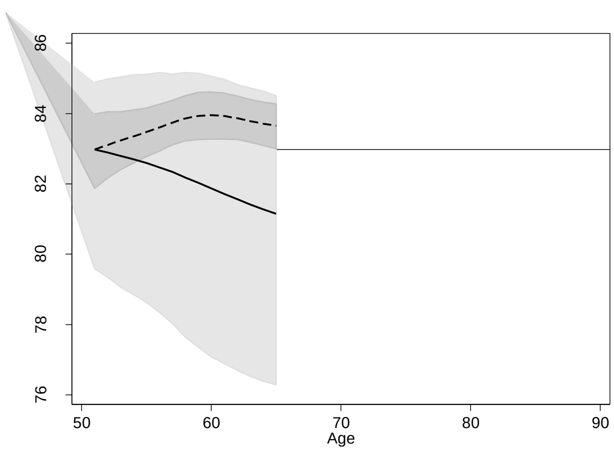
b. U.S. will not experience economic recession
- - - cross-sectional profile; ─── cumulative slopes



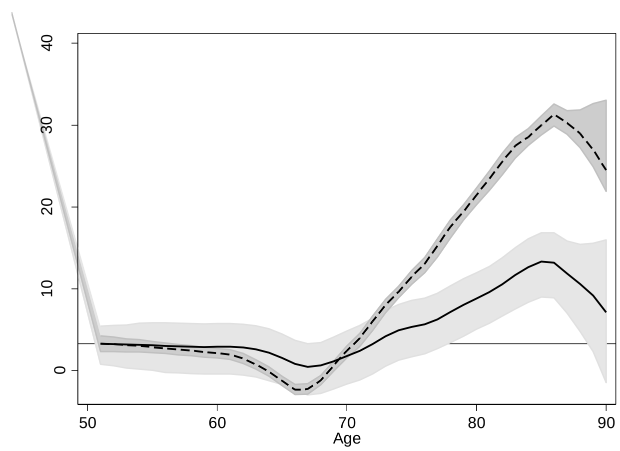
c. Sunny day tomorrow (movers excluded)
- - - cross-sectional profile; ─── cumulative slopes



d. Income will keep up with inflation
- - - cross-sectional profile; ─── cumulative slopes



e. Will not lose job
- - - cross-sectional profile; ─── cumulative slopes



f. Survival to specific age
(difference from life table probabilities)
- - - cross-sectional profile; ─── cumulative slopes

Figure 1. Age profiles of optimism

selection: the question is asked from those that are employed, and those with higher expectations are more likely to stay employed than those with lower expectations.

In contrast to the other five variables, the cross-sectional profiles of survival expectations already takes selection and cohort effects into account and thus show the true age effects. Recall that we transformed the answers to the survival question by taking a difference from the corresponding probabilities implied by the life tables. Those life table probabilities already condition on cohort (as they are calculated for each year separately) and selection (as they show the probability of survival conditional on being alive for every year of age). In contrast, here the profile built up from cumulative differences is biased because they condition on survival to the next survey wave. That way, for each year of age, they select the people with higher survival probability than average. Because these respondents had higher than average probability to begin with, the change in their probabilities is smaller. Because the force of mortality and, therefore, selection accelerates with age, the divergence between the two lines increases with age.

The increase in optimism about life expectancy for those over age 70 shown by the dashed line in Figure 1f is consistent with findings of Hudomiet and Willis (2013) for HRS and Hurd and Rohwedder (2006) using SHARE data from Europe. One could speculate that this pattern is consistent with Carstensen's (2006) theory that the elderly focus increasingly on emotionally rewarding short term goals. For example, their optimistic survival beliefs may allow them to focus on planning a trip or anticipating the birth of a grandchild without needing to worry about the possibility that they may not live to experience the pleasureful event. From an economic perspective, in the absence of full anuitization, it is rational for an individual to maintain a buffer stock of wealth as a precaution against outliving one's assets. Optimism about life expectancy could represent a short-hand way of dealing with uncertainty about the length of life by signaling a need to maintain more wealth than would be required with more the more realistic expectations contained in life tables.

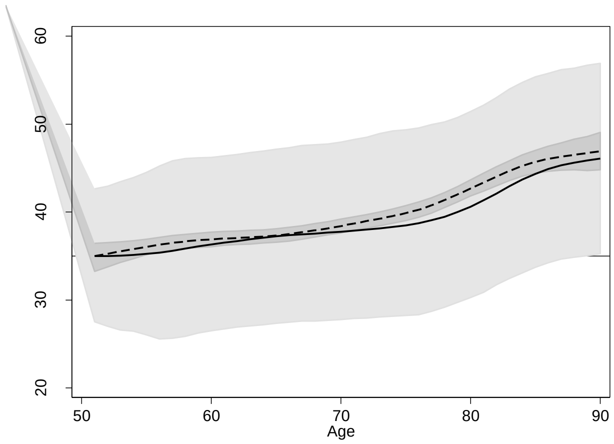
Age Profiles of Uncertainty. We now show the age profiles of our measures of uncertainty. Figure 2 shows our preferred measure, the fraction of "don't know" and 50 per cent answers. Figure 3 shows the fraction of don't know answers only. Similarly to the optimism measures, these are adjusted by the year-month of the interview according to formula (2). Also similarly to the optimism measures, we discarded the sunny day answers of movers. However, in contrast to the optimism measures, we did not adjust survival expectations to life table probabilities here in order to maintain retain the 50 per cent answers.

The cross-sectional age profile of uncertainty is positive in four cases, zero for job loss expectations, and non-monotonic for survival expectations. Whenever the cross-sectional profile of uncertainty is monotonically increasing, the cleaner age profile is also increasing. While the increase in the cleaner age profiles is statistically significant in only one of those four cases, it is jointly significant for the other three as well. The least precisely estimated increase corresponds to job loss expectations, which stops at age 65.

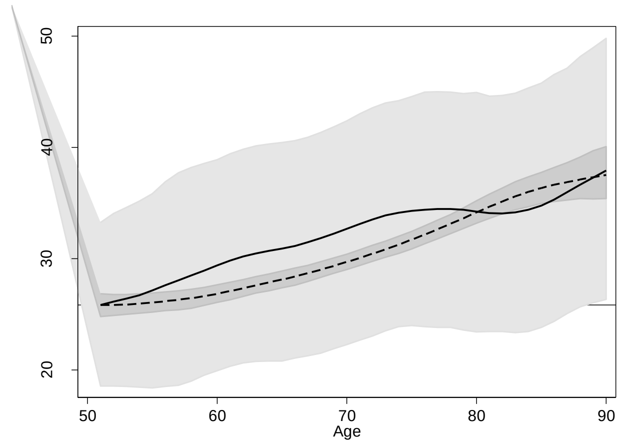
When uncertainty is measured by the fraction of don't know answers only, uncertainty in survival expectations declines more strongly. Taken together, these results suggest that there is a general increase in people's propensity to give 50 per cent and don't know answers, but the tendency to say don't know as opposed to 50 per cent as an answer increases significantly with age.

The figure that does not show a positive effect is survival expectations: uncertainty does not change significantly until age 70 and decreases thereafter. This pattern is driven largely by the 50 per cent answers, and the same answers are responsible in part for the mirroring age profile of survival optimism. When uncertainty is measured by the fraction of don't know answers only, uncertainty in survival expectations cases increases significantly with age, similarly to the other cases.

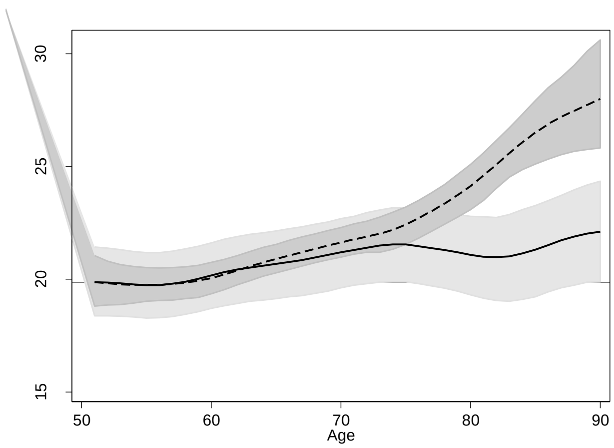
Taken together, the results suggest that aging may have a general negative effect on optimism and a general positive effect on uncertainty, although these effects are not universal. In the remainder of the paper we investigate the role of cognitive decline in explaining these general age effects.



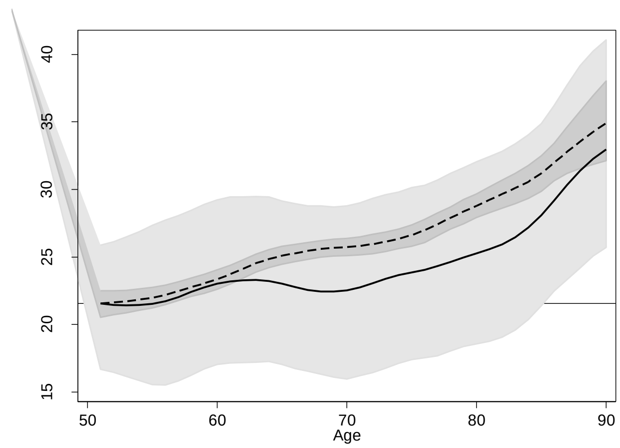
a. The stock market will go up
- - - cross-sectional profile; ─── cumulative slopes



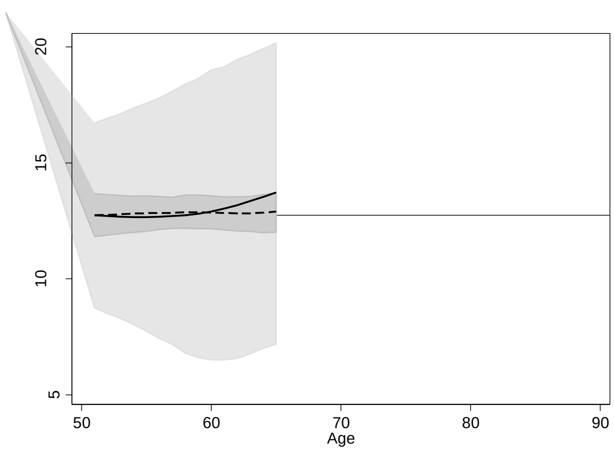
b. U.S. will not experience economic recession
- - - cross-sectional profile; ─── cumulative slopes



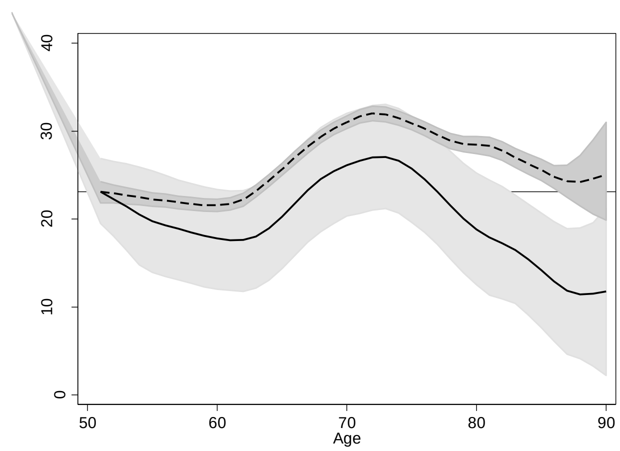
c. Sunny day tomorrow (movers excluded)
- - - cross-sectional profile; ─── cumulative slopes



d. Income will keep up with inflation
- - - cross-sectional profile; ─── cumulative slopes

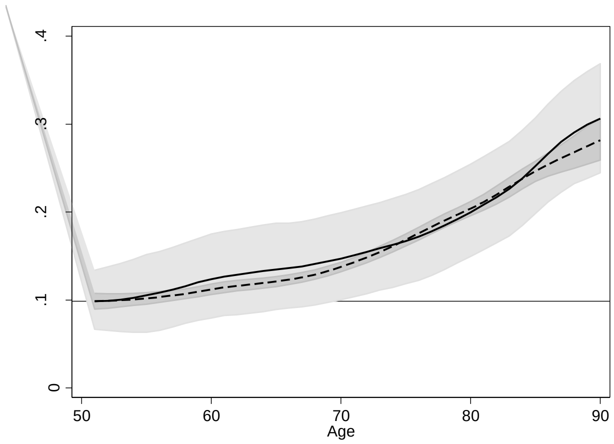


e. Will not lose job
- - - cross-sectional profile; ─── cumulative slopes



f. Survival to specific age
- - - cross-sectional profile; ─── cumulative slopes

Figure 2. Age profiles of uncertainty



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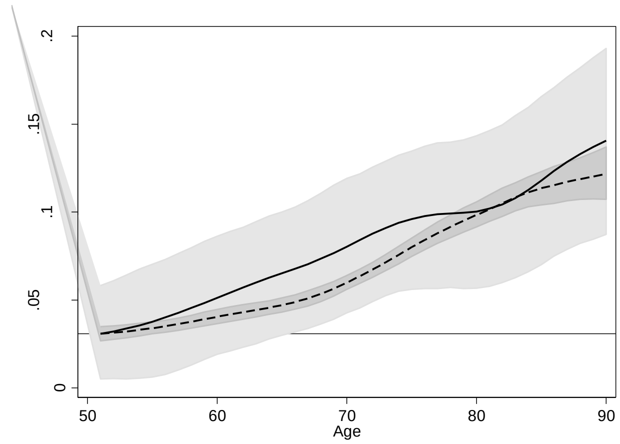

U.S. will not experience economic recession
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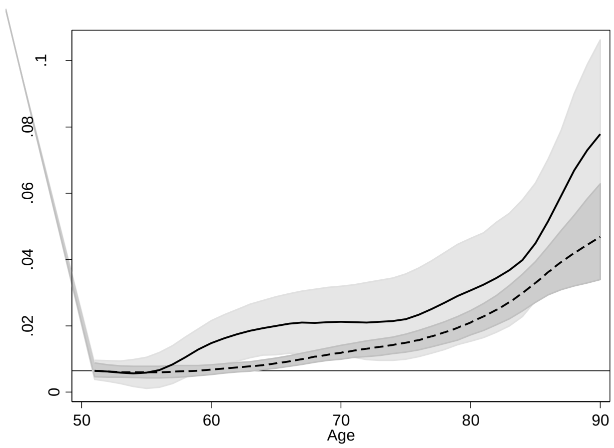
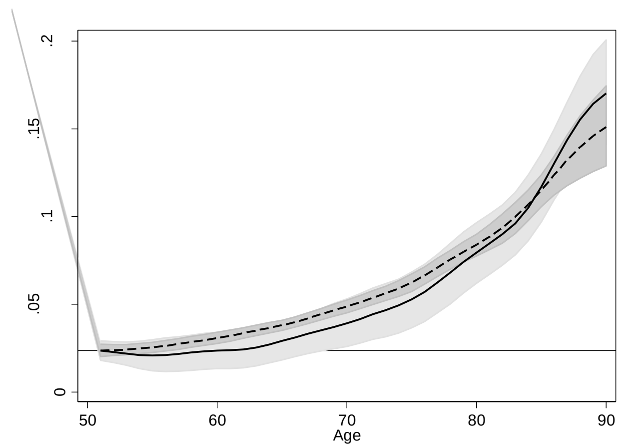
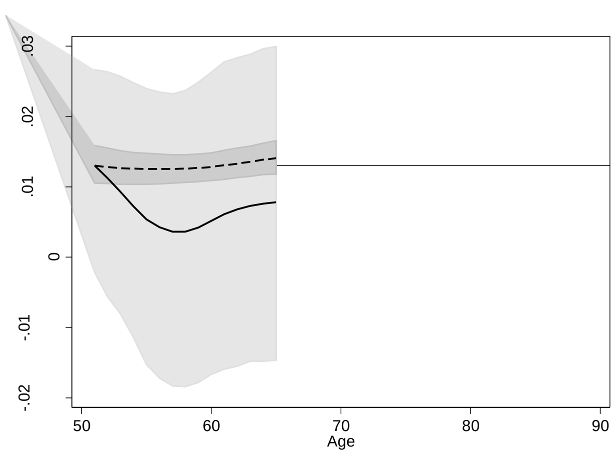


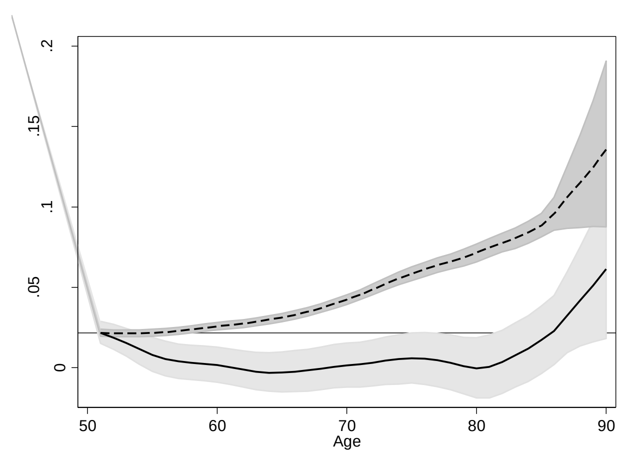
Sunny day tomorrow (movers excluded)
- - - cross-sectional profile; ─── cumulative slopes



Income will keep up with inflation
- - - cross-sectional profile; ─── cumulative slopes



Will not lose job
- - - cross-sectional profile; ─── cumulative slopes



Survival to specific age
- - - cross-sectional profile; ─── cumulative slopes

Figure 3. Age profiles of the fraction of don't know answers

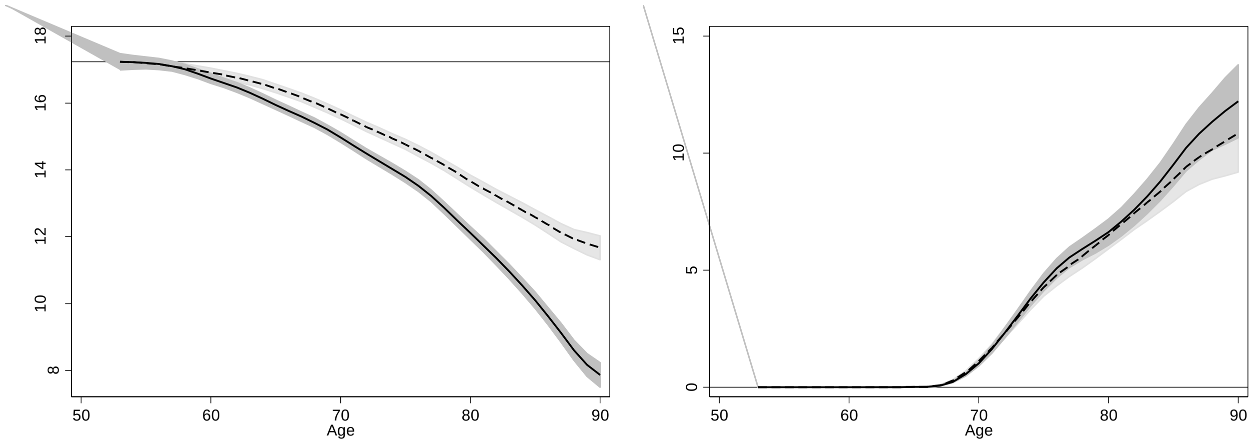
Cognitive decline

Cognitive functioning declines with age in the age range of our sample. Fluid aspects of intelligence — the ability to think and reason — peak in early adulthood and decline afterwards, while more crystalized aspects — acquired knowledge — may keep improving over much of old age and start declining only later (Horn and Cattel, 1967; Horn and McArdle, 2007; McArdle and Willis, 2011). The decline in fluid cognitive functioning is a normal phenomenon in the age range of our sample, but some people experience abnormally strong declines to dementia. Most people do not experience dementia, but even among those who experience normal decline, the rate of cognitive decline can vary considerably

Short-term memory and awareness follow age patterns that are very similar to fluid aspects of intelligence (McArdle, Ferrer-Caja, Hamagami and Woodcock, 2002.) Our 27-score measure of cognitive functioning is a combined measure of short-term memory, awareness and numerical reasoning. It should therefore exhibit age patterns similar to fluid intelligence: apart from the onset of dementia, the measure should show a steady and relatively stable decline. Agarwal, Driscoll, Gabaix and Laibson (2009) show that three tests in the HRS out of the four we use exhibit this age pattern.

Figure 3 shows the age profile of the 27-score measure of cognitive functioning and the probability of dementia. For each measure, we show both the cross-sectional profiles and the age profile built from cumulative slopes (as defined in equation 1). The left panel is analogous to the graphs presented by Agarwal, Driscoll, Gabaix and Laibson (2009) in their figure 4, but we use slightly different samples, a combined measure and show confidence intervals as well. Despite the differences, the left panel of the figure shows a very similar picture to the ones presented by Agarwal, Driscoll, Gabaix and Laibson (2009). The cognitive score shows a steady decline with age, the cross-sectional profile is above the pure age profile, and the divergence between the two is stronger after age 75. These results suggest strong and steady cognitive decline on average, and positive selection on cognitive capacity that becomes strong in later ages. The figures are also consistent with increasing fluid cognitive scores for younger cohorts, known in the psychology literature as the "Flynn-effect" (Flynn, 1987).

The right panel of figure 3 shows an analogous graph featuring the estimated probability of dementia. The age profile of the predicted probability of dementia shows a steady and strong increase after age 67 (it is zero earlier). Similarly to the cognitive score, the cross-sectional profiles show a flatter profile, indicating positive selection or positive cohort effects, but the difference here is not statistically significant.



27-item cognitive score
- - - cross-sectional profile; ─── cumulative slopes

Predicted probability of dementia one year after interview (Hurd et al, 2013)
- - - cross-sectional profile; ─── cumulative slopes

Figure 3. Age profiles of cognitive decline

Taken together, the age pattern of cognitive decline and the general age patterns in expectations may suggest a direct relationship between the two. After all, forming expectations is a cognitive exercise so the relationship seems natural. On the other hand, an important cognitive aspect of expectations is people's knowledge about the domain of the phenomena. Knowledge is a crystalized form of intelligence, and crystalized intelligence does not decrease together with decline in fluid cognitive functioning (Horn and Cattle, 1967). Theoretical arguments by cognitive psychologists and economists (McArdle and Willis, 2011) as well as neuroscientists (Reuter-Lorenz and Park, 2010) suggest that crystalized intelligence may stay high even if fluid intelligence experiences steady decline. Moreover, aging likely affects preferences as well (see, e.g., Carstensen, 2006) that can influence the incentives to acquire and process information and knowledge that shape expectations. It is therefore possible that the effect of aging on expectations operates through mechanisms that are not directly related to the decline of cognitive functioning.

We investigate this question making use of individual heterogeneity in the rate of cognitive decline. If cognitive decline leads to changes in optimism and uncertainty, people who experience stronger decline in cognitive functioning should experience more pronounced changes in their optimism and uncertainty.

Measurement issues and the risk of spurious relationships

Unfortunately, measured heterogeneity in cognitive decline and changes in expectations measured in the same survey may show spurious relationships instead of relationships of true cognitive decline and changes in expectations that are relevant in real-life situations. Heterogeneity in measured changes of cognitive functioning includes variation due to short-term idiosyncratic factors as well as pure measurement error in addition to true variation in the rate of cognitive decline. Similar idiosyncratic variations are likely to influence survey answers to the expectations questions. To facilitate the discussion, we label all additional variation as "noise" and true variation in cognitive decline as "signal". Noise may distort the measured relationship between cognitive decline and expectations if identified from the same survey, in two ways. First, if noise in cognitive decline is independent of potential measurement error in the optimism and uncertainty measures, a regression with cognitive decline on the right-hand-side will produce slope coefficients that are biased towards zero. This is a classical measurement error situation. However, noise in cognitive decline and noise in the optimism and uncertainty measures may be correlated. Variation in effort to answer survey questions from interview to interview for the same individual might induce such a correlation. An interview with lower effort input from the respondent may result in lower scores for the cognitive tests and a higher propensity to give "don't know" or "50 percent" answers to the expectation questions at the same time. This may induce a spurious relationship between measured cognitive decline and measured uncertainty. Whether the noise is classical or correlated, the magnitude of the bias is larger if the noise-to-signal ratio is larger.

Note that these arguments may be relevant for the relationship of changes in other variables measured in the same survey if they, too, are subject to considerable noise. The issue is not whether the relationships are causal but whether the relationships measured from survey data correspond to relationships between the phenomena themselves as opposed to pure survey noise. There is no foolproof way to deal with survey noise. Our strategy in this paper is to construct measures of age-related changes that are least affected by survey noise, and tosearch for circumstantial evidence to see whether the measured relationships can be driven by noise.

A natural choice of analysis would relate wave-to-wave changes in measured expectations to wave-to-wave changes in the cognitive scores. But those first-differenced measures are also the most affected by survey noise. In order to mitigate the bias, we carried out our analysis in individual slopes. For each individual, we regressed the cognitive score on their age at the interview (measured to monthly precision) and saved the coefficients from that regression. For each individual, the slope measure of cognitive decline is the slope coefficient from this regression. Then we performed similar individual regressions for each measure of expectation, after adjustments to the year-month of the interview and the other adjustments we described earlier.[7] We restricted the individual regressions to individuals with 3 observations or more. The maximum number of observations is 7 for the cognitive score and smaller for the measures that are not available in every survey wave.

Regressions of the slope measures of changes of expectations on the slope measures of cognitive decline identify the relationship from between-individual heterogeneity only. The slope measures of cognitive decline are characterized by a lower noise-to-signal ratio (see the evidence below). Therefore, regressions on the slope measures produce estimates that are biased to smaller extent than the results from regressions in first differences. The bias is reduced further if the sample is restricted to individuals that have a relatively large number of observations used in the individual regressions that

[7] These include flipping of negative events, defining survival optimism as the difference from life tables, and restricting sunshine data for those who do not change residence.

estimate the slope measures. Analyzing individual slopes is in the spirit of the latent growth modeling technique used by McArdle, Ferrer-Caja, Hamagami and Woodcock (2002).

Table 3 shows summary statistics on the age-adjusted first difference of the cognitive score variable (the wave-to-wave difference of the cognitive score divided by wave-to-wave difference in age) and the age-adjusted slope measure of the cognitive score (the slope coefficients of the individual regressions of cognitive score on age). The mean of the cognitive change measures is the same. Aging by one year is associated with a decline in the cognitive score by 0.2 points approximately. At the same time, the variance of the first difference measure is substantially higher than the variance of the slope measure.

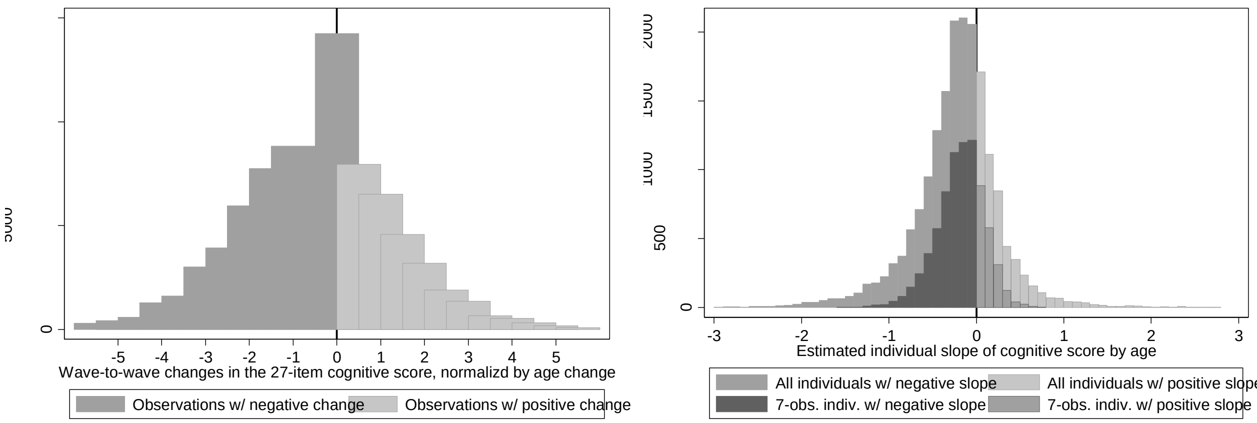
Table 3. Summary statistics of the age-adjusted first difference of cognitive score and the age-adjusted slope of cognitive score

	First difference[a] (1)	Slope measure[b] (2)
Unweighted		
Mean	−0.22	−0.22
Standard deviation	1.85	0.52
Weighted by HRS person weights		
Mean	−0.19	−0.18
Standard deviation	1.86	0.54

[a] Wave-to-wave change in the cognitive score divided by wave-to-eave change in the age of the respondent.
[b] Estimated individual slopes of the cognitive score from individual-specific regressions on age at the interview.

Figure 4 shows histograms of the first-differenced measure of cognitive decline and the individual slope measures. The graph on the slope measures includes the histogram of all slope estimates as well as the histogram of the slope estimates from the subsample of individuals with the maximum number of observations, which is 7. Within each histogram, lighter colors indicate positive measured changes in cognitive functioning. Positive changes are unlikely to reflect true long-term changes in cognitive functioning because the cognitive measure assesses fluid aspects of cognitive functioning, which typically do not improve with age in this age range.

The histograms show the wide dispersion of the first-differenced measure and the narrower dispersion of the slope measure. The distribution of the slope measure is even more concentrated if it is restricted to the subsample of respondents with the maximum number of observations. There is some excess mass around zero for the first-differenced measure, which is an artifact of normalizing the change in the cognitive measure. It is a small integer so that noninteger changes in age leave zero changes in the cognitive score zero but lead to a spread of all non-zero changes. Besides the wide distribution, the histograms highlight the non-negligible fraction of positive measured changes. The fraction of positive changes is 39 percent for the first-differenced measure, 29 percent for the slope measure and 25 per cent for the slope measure in the maximum-observation subsample. The histograms support the assumption that the slope measures have considerably lower noise-to-signal ratio, especially if restricted to the maximum-observations subsample.



First-differenced measure of cognitive decline   Individual slope measure of cognitive decline

Figure 4. Distribution of the individual measures of cognitive decline

We can examine changes in the way the data were collected to provide further evidence on the noise in the cognitive measures. We analyze the effects of wave-to-wave changes in the mode of interview and the identity of the interviewer on the level of and the variation in the cognitive measures. In the HRS, the baseline interview with each respondent is a personal interview; these occurred in 1992, 1998, 2004 and 2010. Before 2006, the normal mode of subsequent interviews is by telephone for persons under age 80 and in person for those over age 80. (However, a small number of respondents request a change from the normal mode and HRS honors these requests.) In 2006, the HRS initiated an “enhanced face-to-face” interview to collect biomarkers and physical performance data. A random half of the longitudinal sample was selected for enhanced personal interview in 2006 with the other half receiving a personal interview in 2008. The 2006 random half received a second enhanced interview in 2010. All of these survey design features lead to changes in the survey mode from telephone to personal and vice versa. The mode of interview changes almost half of the time between two interviews, and these changes are roughly equally split between changes from telephone to personal and vice versa. In 70 percent of the times, the interviewer also changes from wave to wave. The two changes are weakly correlated: change of the interviewer is 12 percentage points more likely when the mode of interview changes.

Change of the survey mode and change of the interviewer may increase noise in the measures for various reasons. Both the mode of the interview and the match between interviewers and respondents can affect the noise in the survey answers. Effects on the effort respondents put into answering the survey questions may induce variation in the cognitive score and the propensity to give uncertain answers to the expectation questions. Effects on the attitudes of the respondents may induce noise in the optimism of the expectation answers.

Table 4 shows the results. The first column shows the results from regressions on the first difference of the cognitive score. The second column show results from regressions on the squared residuals of the regression in the first column. Each regression has four main right-hand-side variables, whether there was a change in the mode of interview, whether the mode of interview was personal and unchanged, whether the mode of interview changed from personal to telephone, and whether it changed from telephone to personal. The regressions control for a full set of year of age dummies and year-month dummies to capture age effects and time effects that may be correlated with changes of the interviewer and the survey mode.

Table 4. Change of interviewer, change of survey mode and the mean and the variance of changes in the cognitive score

	First differenced cognitive score	Squared residual from regression on first differenced cognitive score
Change of interviewer	-0.03	0.3**
	(0.01)+	(0.1)
Interview mode unchanged	0.03	-0.7**
personal	(0.02)	(0.1)
Interview mode change	0.12	0.3**
personal to phone	(0.02)**	(0.1)
Interview mode change	-0.02	0.1
phone to personal	(0.02)	(0.1)
Year of age fixed effects	YES	YES
Year-month fixed effects	YES	YES
R-squared	0.006	0.014
Number of observations	83,673	83,673

Standard errors clustered at household level in parentheses.
+ significant at 10%; * significant at 5%, ** significant at 1%.

The most important results of table 4 are in column (2): the wave-to-wave change of the interviewer and some change in the survey mode are associated with a significantly larger variance of the measured change of the cognitive score. Compared to individuals with phone interview in both waves with the same interviewer, the variance of the change of the cognitive score is lower for individuals with personal interview in both waves, and it is higher for individuals whose interview changes from personal to telephone. Change of the interviewer is also associated with higher variance. Column (1) shows that decline in the cognitive score is less negative for individual whose interview changes from personal to telephone, and change of the interviewer is weakly associated with stronger decline by 0.03. While some of the associations with the first differenced score may show causality from cognitive decline to changes in the data collection, the association of the changes with higher variance is consistent with some of the variance being the result of survey noise.

We have estimated similar regressions for changes in optimism and uncertainty. The results of those regressions indicate that the associations with changes of survey mode are mixed, but there is a significant association between the change of the interviewer and the variance of the first differenced measures of optimism and uncertainty for many expectation questions. Together with the results of table 4, these indicate the association of the expectation measures and cognitive decline measured by regressions estimated in first differences may be identified in part from variation in noise. As noise in first-differenced cognitive scores is correlated with noise in the first-differenced dependent variables, coefficients in such regressions are likely to be biased away from zero. Results of those regressions strong negative associations between the change of the cognitive score and changes in optimism and positive associations between the change of the cognitive score and changes in uncertainty. However, the potentially spurious nature of those associations is supported by the fact that the estimated relationships are very similar if they are identified from only positive changes in the cognitive score, where the variation is likely to be dominated by noise.

Expectations and cognitive decline

Our preferred specification for estimating the association of changes in expectations with cognitive decline uses individual slope estimates instead of first differences. Because of their lower noise-to-signal ratio, using the individual slope estimates in regressions of expectations on cognitive score are likely to result in lower bias. Tables 5 and 6 show the results of the regressions in which the left-hand-side variables are the individual slope estimates of optimism and uncertainty, respectively, for the six probability questions of our analysis. In each regression, the main right-hand-side variable is the slope of the cognitive score, which we multiplied by negative one in order to represent cognitive decline. A positive coefficient would imply that cognitive decline is associated with an increase in our measures of optimism or uncertainty. This coefficient is identified from variation in the average rate of cognitive decline across individuals. That rate of decline is estimated from separate regressions for each individual with 3 to 7 observations. The bias to the coefficient on this variable should be smaller for individuals with 7 observations than for individuals with fewer observations, a fact that we shall utilize when conducting robustness checks.

The individual slopes of left-hand-side variables and the cognitive score are calculated from individual regressions with age, measured to monthly precision, on the right-hand-side. We adjusted each optimism and uncertainty measure to deviations from year-month fixed effects before estimating the individual slopes. The rest of the right-hand-side variables consist of the age of the individual at baseline (the first observation of the cognitive score) normalized to be zero at age 51; the dependent variable at baseline as predicted from the individual slope regressions (normalized to have mean zero); and the cognitive score at baseline as predicted from the individual slope regressions (normalized to have mean zero).

The constants of the regressions show the change in the left-hand-side variables that correspond to aging by one year, measured at age 51, if the dependent variable and the cognitive score are at their average values at baseline and cognitive decline has zero slope. The coefficient on the age at baseline variable corresponds to nonlinearity in the pure age effect :it shows how the age-related change in the left-hand-side variables changes with age. The coefficient on the dependent variable at baseline shows the relationship of the individual slopes of the left-hand-side variables and their initial values (holding the other variables constant), where the initial value is predicted from the individual-specific regressions. Mean reversion, whether due to noise or other idiosyncratic variation in the left-hand-side variables, would imply a negative coefficient. The coefficient on the cognitive score at baseline variable shows the correlation between the average change in the left-hand-side variable and the level of cognitive score at the first observation (holding the slope of the cognitive score and the other variables constant), where the value at the first observation is again predicted from the individual regressions. Here mean reversion may be captured by this coefficient having the same sign as the coefficient on the cognitive decline variable, because the decline variable is the negative of the average change of the cognitive score.

Table 5. Cognitive decline and trends in optimism: estimates from the regressions on individual slopes with respect to age

	survival (adjusted) [a]	sunny day[a]	income growth[a]	job loss[a]	stock market[a]	economic depression[a]
Decline in the cognitive score[b]	0.04	-0.58	-0.36	-0.47	-0.62	-1.32
	(0.12)	(0.24)*	(0.15)*	(0.23)*	(0.15)**	(0.23)**
Age at baseline[c]	0.08	0.01	0.00	0.03	-0.05	0.03
	(0.01)**	(0.01)	(0.01)	(0.02)	(0.01)**	(0.01)**
Dependent variable at baseline[d]	-0.07	-0.25	-0.10	-0.14	-0.14	-0.17
	(0.00)**	(0.00)**	(0.00)**	(0.00)**	(0.00)**	(0.00)**
Cognitive score at baseline[e]	-0.01	0.19	0.10	0.12	0.13	0.20
	(0.01)	(0.03)**	(0.02)**	(0.03)**	(0.02)**	(0.03)**
Constant	-0.49	-0.23	-0.14	-0.36	0.17	-0.18
	(0.07)**	(0.16)	(0.09)	(0.11)**	(0.08)*	(0.13)
R-squared	0.23	0.53	0.32	0.38	0.43	0.30
Number of observations	14080	9841	13997	4225	12311	10980

[a] Estimated individual slopes of the probability answers in percentage terms (from individual-specific regressions on age; the probability answers are adjusted to deviations from year-month fixed effects). The survival probability answers are taken as their difference from the corresponding probabilities calculated from the life tables for people of the same age and gender
[b] Negative of the estimated individual slopes of cognitive score (from individual-specific regressions on age)
[c] Age measured at the first observation of cognitive score, normalized to age 51.
[d] The dependent variable at its first observation, predicted from the individual regressions, normalized to have mean zero.
[e] The cognitive score at the first observation, predicted from the individual regressions, normalized to have mean zero.
Standard errors clustered at household level in parentheses. + significant at 10%; * significant at 5%, ** significant at 1%.

The results show a modest but statistically significant association between the rate of cognitive decline and the average change in the level of expectations for all probability questions except for survival. The average rate of decline in the cognitive score for every additional year of age is 0.2 (this is also the 55^{th} percentile of the distribution). Individuals with 0.1 point higher rate, who would be at the 70^{th}

percentile of the distribution of measured cognitive decline, experience, on average, 0.04 to 0.13 percentage points decline in the level of their probability answers for every additional year of age. These correspond to 1 to 2 per cent of the standard deviation in the slope measures of the left-hand-side variables. Calculated for the 12-year horizon that the data span, individuals with cognitive decline at the 70th percentile would experience 0.5 to 1.5 percentage points decline in their probability answers, which is a small but non-negligible change. The magnitudes are hard to assess not only because these coefficients may still be biased in unknown directions, but also because of the strong measurement error that is likely to remain in the slope estimates of the left-hand-side variables. The robust negative coefficients on the dependent variable at baseline suggest strong mean reversion, highlighting the importance of noise in the left-hand-side variables.

The exception to the negative association with optimism is the survival expectation: people with higher rate of cognitive decline do not experience any difference in the change in their survival expectations from individuals with lower rates of cognitive decline.

The coefficient on the baseline level of cognitive decline is positive in five of the six cases and zero in case of survival expectations. When positive, these partial correlations show that people with higher levels of cognitive functioning have lower rates of decline in optimism, holding the rate of decline and age constant. The coefficients are positive whenever the coefficient on the cognitive decline is negative, providing additional support for the positive relationship between cognitive functioning and optimism. Note that our finding of mean reversion due to noise in the cognitive decline variable would result in same sign of the level and the decline variable because the decline variable is the negative of the change. The fact that we do not find the same sign suggests that the noise in cognitive decline is not strong enough to overturn the positive substantive association.

The constants and the coefficients on age in the optimism regressions provide a heterogeneous picture. Optimism about income growth and sunshine do not show significant age profiles holding cognitive decline and baseline cognitive functioning constant. Optimism about the stock market shows a weak positive age profile starting at age 51 that turns negative very quickly to reach a strong negative slope of negative one percent by age 70, even holding the rate of cognitive decline and the baseline level of cognitive functioning constant (at least as they are measured in our data). Optimism about job loss shows a negative age profile at age 51 that may or may not dampen with age as the coefficient on age is positive but insignificant. The age profile of optimism about economic depression is flat at age 51, holding the level and the change in cognitive functioning constant, but it shows a small but statistically significant secular increase at later ages, reaching a slope of 0.7 at age 80. The estimated age profile of survival expectations is not affected by either the decline or the level of cognitive functioning, and it thus shows the same picture as on figure 1: survival optimism decreases initially but turns into an increase at around age 65.

Taken at face value, the estimates suggest that cognitive decline is associated with declining optimism in domains of private economic conditions, aggregate economic conditions and sunny weather. While deteriorating private economic conditions may be affected by declining cognitive functioning for fundamental reasons, declining optimism in the more general domains is more likely to reflect some more general association between age-induced decline in fluid cognitive functioning and less optimistic thinking about general issues. Growth in optimism about survival expectations with age is an important exception to this phenomenon. As discussed earlier, one for this may have a basis in psychological tendencies for older people to focus on emotional sources of future satisfaction without worrying about whether they will be alive to enjoy them. Another reason is that optimism about survival chances may serve as a heuristic device to help people maintain sufficient wealth to enable them to maintain their living standards should they survive to an exceptional old age.

Some of the variation in observed cognitive decline is due to some people entering in phase of dementia. Unfortunately, a joint analysis of the decline in the cognitive score and the increasing estimates for the probability of dementia is not possible due to the strong correlation between the two and to the fact that the large part of the variation in dementia probabilities is concentrated in the relatively small sample of individuals above 75 years of age. In order to see whether the estimates in table 5 reflect associations with the onset of dementia, we re-estimated all regressions on the subsample of respondents whose estimated probability of dementia stayed below 5 percent in all survey waves they were interviewed. The results are very similar to the ones presented in table 5, with the exception of sunny day optimism, where the association with cognitive decline ceases to be significant.

We performed several robustness checks. First, we restricted the sample to individuals with the maximum number of observations used in the slope regressions, which is 7 for the cognitive score. As suggested by the right panel of figure 4, the noise in the slope estimates is substantially smaller in this subsample. The coefficients on the cognitive decline variable are very similar to, and most case stronger than, those presented in table 5. This suggests that the coefficients in table 5 show genuine associations.

Second, we controlled for symptoms of clinical depression both in the first and the last observation of reach individual. This robustness check was motivated by the fact that cognitive decline is associated with deteriorating health conditions, and the deteriorating health conditions may be responsible for the observed decline in the levels of expectations. That worry should be strongest for the survival expectations where, in spite of it, we do not see any association with cognitive decline. However, some subtle changes through depressive symptoms may operate in the case of all other expectations. Controlling for depressive symptoms should lead to weaker coefficients if that worry is warranted. But it does not: whether estimated for the whole sample, the sample with maximum number of observations or individuals with low probability of dementia through all interviews, controlling for depressive symptoms does not change the results.

Finally, we re-estimated all regressions on the separate subsamples with declining and increasing slope estimates for the cognitive score. As we have argued, positive slopes are more likely to reflect idiosyncratic positive changes in the measured cognitive score variable than genuine long-run improvement in cognitive functioning. Therefore, if the association between cognitive decline and declining optimism is genuine, it should be strong in the subsample of declining cognitive scores, and it should be weak in the subsample of increasing cognitive scores. The results are in line with these expectations in general. In most cases, the coefficient estimates on the cognitive decline variable are stronger in the subsample of declining slopes than in the entire sample, and none of them is statistically significant in the subsample of increasing slopes.

After establishing some fairly general associations with respect to age-related changes in optimism, we turn to age-related changes in uncertainty. Table 6 shows results in a structure similar to table 5.

Table 6. Cognitive decline and trends in uncertainty: estimates from the regressions on individual slopes with respect to age

	survival (unadjusted) [a]	sunny day[a]	income growth[a]	job loss[a]	stock market[a]	economic depression[a]
Decline in the cognitive score[b]	0.15	1.38	0.19	0.31	-1.05	0.02
	(0.27)	(0.47)**	(0.26)	(0.38)	(0.38)**	(0.45)
Age at baseline[c]	-0.04	-0.04	0.00	-0.03	-0.02	-0.01
	(0.01)**	(0.02)+	(0.01)	(0.03)	(0.01)	(0.02)
Dependent variable at baseline[d]	0.00	0.09	0.00	0.08	-0.00	0.06
	(0.00)	(0.01)**	(0.00)+	(0.01)**	(0.00)	(0.00)**
Cognitive score at baseline[e]	0.03	-0.14	0.01	-0.04	0.09	-0.03
	(0.03)	(0.05)**	(0.02)	(0.04)	(0.04)*	(0.05)
Constant	0.16	0.37	0.11	0.20	0.39	0.41
	(0.13)	(0.31)	(0.14)	(0.18)	(0.18)*	(0.23)+
R-squared	0.00	0.03	0.00	0.08	0.00	0.02
Number of observations	15,718	9,841	13,997	4,225	12,311	10,980

[a] Estimated individual slopes of the percent of missing or 50 percent answers (from individual-specific regressions on age; the uncertainty measures are adjusted to deviations from year-month fixed effects)
[b,c,d,e] See notes to table 5.
Standard errors clustered at household level in parentheses. + significant at 10%; * significant at 5%, ** significant at 1%.

In contrast with the statistically significant results on optimism, the estimated association of the rate of cognitive decline with the rate of increase of uncertainty is not significantly different from zero in four out of the six cases. In the two significant cases the sign is opposite: higher rates of cognitive decline seem to be associated with higher increases in the rate of the propensity to give uncertain answers to the sunny day question but with lower increases in the rate of the propensity to give uncertain answers to the stock market question. In cases where the coefficient on the cognitive decline variable is not significant, the coefficient on the baseline level of cognitive functioning is not significant either. In the other two cases, the coefficients on the levels strengthen the coefficients on the decline: higher initial level of cognitive functioning is associated with a stronger increase of uncertainty about the stock market but a weaker increase of uncertainty about sunshine.

The lack of association between cognitive decline and increasing uncertainty are confirmed by our robustness checks. The results are similar or even weaker when restricted to individuals with 7 observations for the cognitive score or with low probability of dementia, and when depressive symptoms are controlled. As an additional robustness check, we re-estimated all regressions with uncertainty measured as the propensity to give don't know answers only (without the 50 answers). These results are even weaker, with no association between cognitive decline and uncertainty even in the case of sunshine expectations.

Conclusions

This is an exploratory study of the relationship between expectations, aging and cognitive decline—a topic on which little prior research exists. We use data from seven waves of the Health and Retirement Study (HRS) to establish age patterns in optimism and uncertainty in expectations about six different events: survival to a specific age, sunshine, growth of real income, job loss, gains on the stock market and economic depression. Respondents are asked to state their subjective probabilities of the events in the questions. We measure optimism by higher subjective probabilities of positive events and uncertainty by a higher propensity to give "don't know" or "50 per cent" answers.

With the notable exception of survival expectations, we find that optimism decreases and uncertainty increases with age in all of the other five domains, controlling for time, cohort and selection effects. We also find that cognitive decline plays a modest but statistically significant role in explaining the decline of optimism and a less significant role in accounting for the increase of uncertainty. In contrast, optimism about survival chances increases significantly with age and uncertainty decreases. These patterns appear both in (pooled) cross-sectional data and in cumulative slopes estimated from longitudinal changes in expectations in which cohort, time and selection effects are swept out, leaving pure age effects. We argue that the analyses that use cumulative slopes provide less scope for finding spurious relationships between expectations and cognitive decline due to survey noise and thus serve as a robustness check on the patterns we see in the cross-sectional age profiles of optimism and uncertainty.

Our finding of a general pattern of decreasing optimism and increasing uncertainty about sunshine, growth of real income, job loss, gains on the stock market and economic depression is consistent with a pattern of cognitive decline that makes it more difficult for people to acquire and process knowledge and information about events in the world. To the extent that these patterns of survey response reflect beliefs that people act upon in their decisions, we would expect to find that people act with greater caution and take fewer risks as they grow older. Agarwal, et al. (2009) argue that declining cognitive capacity causes older people to make more mistakes in decisionmaking. Our results on expectations suggest that older people may reduce the damage from mistaken decisions by attempting to avoid them altogether. For example, the reduction in the risk of being scammed by purchasing a financial product that one does not understand must be balanced against the potential benefits that might be obtained if, in fact, it is a good product. Increased pessimism and uncertainty would tilt this calculation in favor of no purchase.

Our finding of increased optimism about survival as people age may be consistent with Carstensen's (2006) socio-emotional selectivity theory of aging which posits that people become increasingly selective, investing greater resources in emotionally meaningful goals and activities because of an ever shorter time horizon before death. We speculate that optimism about survival allows the elder to focus on emotionally rewarding short term goals such as planning a trip or anticipating the birth of a grandchild without needing to worry about the possibility that they may not live to experience the pleasureful event. Optimism about survival may also serve an economic purpose as a heuristic that helps people to maintain a buffer stock of wealth as a precaution against outliving one's assets by giving greater weight to the chance of an unusually long life.

It is important to stress that the findings in this paper are exploratory and that our interpretation of them is speculative. We do believe that greater understanding of how probability beliefs are influenced by aging and cognition is a promising line of research. A priority for future research will be to link changing beliefs to behavior and decisions.

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Table A1. Cognitive decline and trends in uncertainty (measured as the fraction of don't know answers): estimates from the regressions on individual slopes with respect to age

	survival (unadjusted)[a]	sunny day[a]	income growth[a]	job loss[a]	stock market[a]	economic depression[a]
Decline in the cognitive score[b]	0.20	0.01	0.40	0.08	-0.04	-0.04
	(0.05)**	(0.00)*	(0.08)**	(0.06)	(0.10)	(0.02)+
Age at baseline[c]	0.01	-0.00	0.01	0.00	-0.02	0.00
	(0.00)*	(0.00)+	(0.00)**	(0.00)	(0.01)**	(0.00)
Dependent variable at baseline[d]	0.00	-0.00	0.00	0.00	-0.00	-0.00
	(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)*
Cognitive score at baseline[e]	-0.03	-0.00	-0.03	-0.01	-0.01	0.02
	(0.01)**	(0.00)**	(0.01)**	(0.01)	(0.01)	(0.00)**
Constant	-0.07	0.06	-0.01	0.00	0.43	0.17
	(0.03)*	(0.00)**	(0.04)	(0.04)	(0.07)**	(0.02)**
R-squared	0.01	0.00	0.01	0.00	0.00	0.00
Number of observations	15,718	9,841	13,997	4,225	12,311	10,980

[a] Estimated individual slopes of the percent of missing or 50 percent answers (from individual-specific regressions on age; the uncertainty measures are adjusted to deviations from year-month fixed effects)

[b,c,d,e] See notes to table 5.

Standard errors clustered at household level in parentheses. + significant at 10%; * significant at 5%, ** significant at 1%.

Table A2. Cognitive decline and trends in uncertainty (measured as the fraction of don't know answers): estimates from the regressions on individual slopes with respect to age. Sample restricted to individuals with maximum number of observations

	survival (unadjusted)[a]	sunny day[a]	income growth[a]	job loss[a]	stock market[a]	economic depression[a]
Decline in the cognitive score[b]	0.09	0.01	0.05	0.15	0.13	-0.22
	(0.14)	(0.01)	(0.15)	(0.14)	(0.21)	(0.10)*
Age at baseline[c]	-0.01	-0.00	0.01	-0.00	0.01	0.01
	(0.00)*	(0.00)	(0.01)+	(0.01)	(0.01)	(0.00)**
Dependent variable at baseline[d]	0.00	-0.00	0.00	-0.00	-0.00	-0.00
	(0.00)*	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)*
Cognitive score at baseline[e]	-0.00	-0.00	-0.01	-0.02	-0.01	0.04
	(0.01)	(0.00)*	(0.01)	(0.02)	(0.02)	(0.01)**
Constant	0.05	0.06	-0.02	0.01	0.04	0.05
	(0.04)	(0.00)**	(0.05)	(0.07)	(0.09)	(0.05)
R-squared	0.01	0.00	0.00	-0.00	0.00	0.01
Number of observations	7,743	6,346	7,751	2,322	6,919	6,724

[a] Estimated individual slopes of the percent of missing or 50 percent answers (from individual-specific regressions on age; the uncertainty measures are adjusted to deviations from year-month fixed effects)

[b,c,d,e] See notes to table 5.

Standard errors clustered at household level in parentheses. + significant at 10%; * significant at 5%, ** significant at 1%.