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Rounding, Focal Point Answers and Nonresponse to Subjective Probability Questions

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Summary

We develop a panel data model explaining answers to subjective probabilities about binary events and estimate it using data from the Health and Retirement Study on six such probabilities. The model explicitly accounts for several forms of "reporting behavior": rounding, focal point "50 percent" answers, and item nonresponse. We find observed and unobserved heterogeneity in the tendencies to report rounded values or a focal answer, explaining persistency in 50 percent-answers over time. Focal 50 percent answers matter for some of the probabilities. Incorporating reporting behavior does not have a large effect on the estimated distribution of the genuine subjective probabilities.

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1. Introduction

Expectations play a crucial role in many economic models. The recent literature on measuring expectations of individuals proposes to use subjective probability questions. Answers to such questions are used more and more frequently to understand if expectations and outcomes are related in a systematic manner, to evaluate if individual behavior changes in response to changing expectations, and to relax assumptions on expectation formation in models with forward looking agents.[2] Commonly, answers to subjective probability questions are heaped to different degrees at multiples of 5 or 10 and item nonresponse is non-negligible. The fraction of "50 percent" answers is often particularly large, and there is evidence that such answers reflect high uncertainty in line with a "50/50 chance" in daily language, rather than indicating a genuine probability of about 50% (Bruine de Bruin *et al.*, 2000). This suggests that answers to subjective probability questions suffer from various types of reporting behavior (rounding, item nonresponse, focal answers) that may reduce the quality of the data and bias substantive conclusions concerning the true subjective expectations. This implies the need to better understand reporting behavior in subjective probability questions.

In this paper, we study the response patterns to six subjective probability questions in the US Health and Retirement Study (HRS). We analyze to which extent the reported probabilities are driven by the genuine underlying probabilities, by rounding, by a tendency to give focal point answers, and by selective item nonresponse. Moreover, we want to analyze the persistence of reporting behavior over time, how such reporting

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[2] See Bernheim (1990), Manski (2004) and Hurd (2009) for overviews of subjective expectations in economic research, and Dominitz and Manski (2006) on eliciting subjective expectations in surveys.

behavior varies with observed and unobserved characteristics, and how accounting for rounding and focal point answers affects the estimates of the determinants of expectations and the distribution of genuine underlying subjective probabilities.

We develop and estimate a panel data model where the response to a subjective probability question is a two-step process. In the first step, an individual chooses either not to respond to a question,[3] to give a focal point answer of 50/50 unrelated to the probability of interest, or to give an answer that is the rounded value of the true probability, where we incorporate rounding to multiples of 1, 5, 10, 25 or 50. Thus, "50 percent" answers can be purely focal point answers as well as the result of rounding.

The HRS includes a variety of subjective probability questions, making it suitable for this study. In addition, its longitudinal nature, large sample size and national representativeness for older age groups (50+) allow in depth study. The six questions we use remained virtually unchanged over several interview years: expectations about the stock market, living to age 75, leaving a bequest, receiving an inheritance, working fulltime after reaching age 62, and having a work-limiting health condition. These questions have been used in a variety of studies examining, for example, the effects of wealth shocks on retirement (Brown *et al.*, 2010), optimal savings behavior (Scholz *et al.*, 2006), the effects of old age social security reforms (Michaud and van Soest, 2008), reverse retirement (Maestas, 2010), the effect of the financial crisis on expectations of stock market returns (Hudomiet *et al.*, 2011), and the predictive power of survival

[3] Our sample is too small to distinguish answers of "don't know" and refusals. See Shoemaker *et al.* (2002) for the differences in determinants of these two types of nonresponse.

probabilities for social security claiming (Hurd *et al.*, 2004) and actual mortality (Hurd and McGarry, 2002). Our model is applied to each of these six questions separately.

While existing studies have analyzed focal answers, rounding, or item nonresponse (see Section 2), this study develops a model incorporating these three forms of reporting behavior simultaneously, exploiting the panel nature of the data: the same respondents got the same probability questions up to nine times over 16 years. Using random effects models, we allow for unobserved factors that make some respondents more likely not to respond at all, to give a 50/50 focal answer, or to round excessively, e.g. to multiples of 25 or 50. The various random effects are allowed to be correlated so that, for example, the model can capture that respondents who tend not to respond may also have a greater tendency to round. This allows us to address the importance of different forms of reporting behavior and their within-respondent persistence over time. Moreover, we analyze how ignoring reporting behavior changes conclusions about distributions and determinants of underlying genuine subjective probabilities.

We first give an overview of possible psychological reasons for item nonresponse, focal point answers and rounding (Section 2). We then describe the empirical model (Section 3). After a description of the data and variables used, including the frequency and patterns of item nonresponse and 50/50 answers in our sample (Section 4), we present the estimation results in Section 5. Section 6 concludes.

2. Reporting Behavior in Subjective Probability Questions

Reporting behavior has its theoretical foundations in the psychology of survey response. Schwarz and Oyserman (2001) distinguish five steps in the answering process: Understanding and interpreting the meaning of the question, Recalling relevant behavior and information, Inferring an answer, Mapping the answer onto the response format, and Editing (deciding on which response to give). The first three steps can be classified as mental processes providing the input for an individual's response, while the last two steps reflect the articulation and reporting process.[4] Item nonresponse, focal point answers, and strong rounding are more likely if any of these five steps is difficult. For example, step 1 can be difficult if the concept of probability is not clear to the respondent. Step 2 will be hard if the process of recall gives insufficient information to infer an answer (for example about work past age 62 if the respondent does not know the firm's retirement policy). Inferring might be difficult because of ambiguity (Fox and Tversky, 1995) or because the answer involves many different parts – for example, the probability of leaving a bequest not only requires assessing current wealth but also future wealth, health, and life expectancy, and the future health and life expectancy of one's spouse. The response format of a probability between 0 and 100 might make the mapping of the answer (step 4) difficult since it does not allow for expressing uncertainty. In the editing phase, the respondent might choose not to give an answer because the topic is sensitive (involving personal wealth, for example). A respondent may then report a socially desirable 50/50 or "don't know" answer rather than a refusal.

These arguments imply that item nonresponse, focal answers, and crude rounding will be more prevalent for questions that are more difficult or refer to less relevant or less well-defined events. The question on the stock market does not refer to the respondent's own situation and may be irrelevant for many individuals. Bruine de Bruin *et al.* (2000) argue that questions like this may lead to more 50/50 answers since the respondent has no control over the outcome. We would, therefore, expect a

[4] We thank an anonymous referee for this classification suggestion.

relatively large share of nonresponse, crude rounding and focal answers for this question. The same applies to the question about a work limiting disability, which is difficult since it involves two components: the expectation of future health events and the assessment whether these would limit work. The latter seems a more ambiguous event than those in the other questions. The questions on bequests and on working past age 62 seem less vulnerable to reporting behavior since they involve familiar and relevant topics and outcomes that can be influenced by the respondent.

Given the important role that understanding and assessing the situation plays when answering the probability questions, we expect the most important individual characteristics predicting reporting behavior to be cognition and education. Other characteristics like income or wealth, age, and gender affect the relevance of the questions and may, therefore, also matter. Race and ethnicity might affect, for example, the choice between answering “don’t know” and a focal “50 percent” because of different social norms. We expect that age is especially important for the probabilities of living to age 75 and working past age 62, since these events will be more concrete the closer they come. Socio-economic status (education, income, wealth) is expected to be associated with knowledge about financial matters, which probably matters most for the stock market expectations and possibly also for bequests and inheritances.

From a psychological point of view, the three forms of reporting behavior that we consider are similar. Existing studies typically focus on one or two of them and use cross-section data. Fischhoff and Bruine de Bruin (1999) and Bruine de Bruin *et al.* (2000, 2002), for example, mainly focus on the presence of focal non-informative 50/50 answers, using the concept of “epistemic uncertainty” for cases where respondents do not know the probability at all. Lillard and Willis (2001) and Kézdi and

Willis (2009) study focal point answers and use them to construct indicators of precision of probabilistic thinking. They find that stock ownership and the fraction of risky assets in a wealth portfolio are positively related to such an index. Manski and Molinari (2010) focus on rounding and, using the concept of identification up to a bounding interval, show that rounding can seriously limit the information on the means of the true underlying probabilities given covariates. With minimal assumptions on the rounding process, they find large and uninformative bounding intervals for the conditional expectations of subjective survival probabilities in the HRS. Our approach is more similar to that of Hudomiet *et al.* (2011) who also account for rounding (and eliminate some "50 percent" answers identified as focal), but in the context of an econometric model with more assumptions than Manski and Molinari, leading to more informative results. Bassett and Lumsdaine (2001) illustrate the existence of systematic errors in subjective responses to probability questions by identifying a common component across subjective responses that is unrelated to the specific question. Their findings suggest that benchmarking subjective probabilities given by individuals who might have had problems understanding the probability question improves inference.

3. A Model of Rounding, Focal Point Answers and Item Nonresponse

In this section we introduce our panel data model explaining the reported subjective probabilities, explicitly accounting for rounding, focal point answers and item non-response. The model combines ideas of the rounding model of Heitjan and Rubin (1990) with those of models that account for misclassified discrete dependent variables (see, e.g., Hausman *et al.*, 1998). We model one subjective probability at a time.

The true (unobserved) subjective probability of respondent *i* in wave *t* is assumed to be driven by a latent variable $y^*_{i,t}$, modeled as follows:

$$y^*_{i,t} = x_{i,t}\beta + \alpha_i + \varepsilon_{i,t} \,. \tag{1}$$

Here $\varepsilon_{i,t}$ is an error term and α_i is a respondent-specific unobserved heterogeneity term that does not vary over time, reflecting, e.g., unobserved factors that make the event referred to in the question less or more likely, or the degree of optimism or pessimism of the respondent. The vector $x_{i,t}$ is a set of (strictly exogenous) observed explanatory variables and β is a vector of parameters to be estimated. Distributional assumptions on $\varepsilon_{i,t}$ and α_i are given below. The (usually unobserved) true probability $y^T_{i,t}$ is the value of $y^*_{i,t}$, censored at lower bound 0 and upper bound 100:

$$y^T_{i,t} = \max(0, \min(y^*_{i,t}, 100)) \,. \tag{2}$$

This implies that true subjective probabilities can be 0 or 100 with positive probability. Even though 0 and 100 may be impossible for objective probabilities (e.g., no one has probability zero of developing a work limiting health problem in the next ten years), it seems possible that respondents *think* their probability is genuinely zero.

The subjective probability (in %) reported by respondent *i* in wave *t* is denoted by $y_{i,t}$, where $y_{i,t}$ is missing if respondent *i* answers “don’t know” or “refuse” and is an integer number between 0 and 100 otherwise. Irrespective of censoring and focal points, it seems obvious from the peaked nature of the distribution of the raw data (see Table 1 below and the histograms in Figures A1-A6 in the appendix) that the observed probabilities are characterized by rounding. Observed probabilities are usually a multiple of 10 or 25, sometimes another multiple of 5, and only occasionally not a multiple of 5. In order to take this into account we explicitly model the rounding process, allowing for rounding to multiples of 50, 25, 10, 5 or 1. Rounding to a multiple of 50 is the maximum form of rounding we consider, leading to answers of 0, 50 or 100; rounding to a multiple of 1 is the minimum extent of rounding allowed for – the survey design did not allow for other answers than integers. Rounding to multiples of 25, 10 or 5 can be seen as intermediate cases. The (partially observed) type of rounding is denoted by $R_{i,t}$:

$R_{i,t} = 1$: The probability is rounded to a multiple of 1

$R_{i,t} = 2$: The probability is rounded to a multiple of 5

$R_{i,t} = 3$: The probability is rounded to a multiple of 10

$R_{i,t} = 4$: The probability is rounded to a multiple of 25

$R_{i,t} = 5$: The probability is rounded to a multiple of 50. (3)

Respondents who know a probability exactly will probably round to the nearest multiple of 1; if they know the probability approximately, rounding to a multiple of 5 or 10 seems plausible. If a respondent only has a rough idea of the range of a probability, rounding to a multiple of 25 or 50 seems likely. Because of the plausible way in which these forms of rounding can be ordered, we will model rounding behavior with an ordered response equation. A natural way to do this is given by:

$$R_{i,t}^* = x_{i,t}\beta^R + \alpha_i^R + \varepsilon_{i,t}^R \qquad (4)$$

$$R_{i,t} = j \text{ if } m_{j-1} < R_{i,t}^* \le m_j,\ j = 1,\ldots,5\,.$$

Here $\varepsilon_{i,t}^R$ is an error term and α_i^R is a respondent-specific unobserved heterogeneity term that does not vary over time, reflecting unobserved respondent characteristics that drive the respondent's extent of rounding; β^R and $m_1,...,m_4$ are unknown parameters. By definition, $m_0 = -\infty$ and $m_5 = \infty$.[5]

Instead of reporting a rounded value of the true subjective probability, respondents may also decide not to report any value ("don't know" / "refuse") or to simply respond "50 percent" as an expression of complete ("epistemic") uncertainty. In the latter case we observe $y_{i,t} = 50$, which we call a "50/50" answer. It does not stem from rounding – even in a case where the true probability is closer to 0 or to 100 than to 50, such a 50/50 answer can be given. A standard way to model the type of answer $D_{i,t}$ is to use the following random effects multinomial logit model with three possible outcomes:

$$u_{i,t}^j = x_{i,t}\beta^j + \alpha_i^j + \varepsilon_{i,t}^j,\ j = 1,2,3;\ D_{i,t} = j \text{ if } u_{i,t}^j \geq u_{i,t}^k, k = 1,2,3 \tag{5}$$

$$\beta^1 = 0;\ \alpha_i^1 = 0$$

$$\varepsilon_{i,t}^j\ i.i.d. \text{ standard Gumbel, independent of } \alpha_i^2, \alpha_i^3 \text{and } x_{i,t} : P(\varepsilon_{i,t}^j \leq z) = \exp(-\exp(-z))$$

The benchmark outcome is $D_{i,t} = 1$: rounding; the other outcomes are "don't know" or "refuse" ($D_{i,t} = 2$) and "50/50" ($D_{i,t} = 3$). The assumptions $\beta^1 = 0; \alpha_i^1 = 0$ are normalizations without loss of generality. The distributional assumptions on the error terms $\varepsilon_{i,t}^j$ lead to the following multinomial logit probabilities, conditional on observed characteristics $x_{i,t}$ and unobserved characteristics α_i^2, α_i^3:

$$P(D_{i,t} = j \mid x_{i,t}, \alpha_i^2, \alpha_i^3) = \exp(x_{i,t}\beta^j + \alpha_i^j) / \sum_{k=1}^{3} \exp(x_{i,t}\beta^k + \alpha_i^k);\ j = 1,2,3. \tag{6}$$

[5] As in the standard ordered probit model, the distances between the cut-off points determine the frequencies of the categorical outcomes, but the parameters themselves do not have a clear interpretation.

In addition to the assumptions on $\varepsilon_{i,t}^{j}, j=1,...,3,$ given above, the distributional assumptions on error terms and (random) individual effects are as follows:

$$\varepsilon_{i,t} \; i.i.d. \; \text{N}(0,\sigma_{\varepsilon}^{2}), \text{ independent of } \varepsilon_{i,s}^{1},...,\varepsilon_{i,s}^{3} \text{ and } x_{i,s}, s=1,...,T. \tag{7}$$

$$\varepsilon_{i,t}^{R} \; i.i.d. \; \text{N}(0,1), \text{ independent of } \varepsilon_{i,s}, \varepsilon_{i,s}^{1},...,\varepsilon_{i,s}^{3} \text{ and } x_{i,s}, s=1,...,T.$$

$$(\alpha_i, \alpha_i^R, \alpha_i^2, \alpha_i^3)' \; i.i.d. \; \text{N}(0,\Sigma_{\alpha}), \text{ independent of } x_{i,s}, \varepsilon_{i,s}, \; \varepsilon_{i,s}^{R}, \text{ and } \varepsilon_{i,s}^{1},...,\varepsilon_{i,s}^{3}, \; s=1,...,T.$$

Here σ_{ε}^{2} is a parameter to be estimated, and Σ_{α} is written as $\Sigma_{\alpha} = \Lambda\Lambda'$, where Λ is a positive semi-definite lower diagonal matrix with parameters to be estimated, so that any arbitrary covariance matrix of the individual effects Σ_{α} is allowed. We expect a positive correlation between α_i^2 and α_i^3 since more uncertain respondents will more often give a focal 50/50 answer but will also be more likely to not respond at all. This also implies that the probability of a focal 50/50 response increases with the tendency to not respond, unlike in a standard multinomial logit model.[6]

The complete model is estimated by maximum simulated likelihood. Due to potential correlation among the various individual effects, not estimating everything jointly may lead to selection bias. Hudomiet *et al.* (2011), for example, discard focal answers and item non-respondents, which in the context of our model would be allowed only if α_i^2 and α_i^3 were uncorrelated with α_i.

For a given respondent *i* the conditional likelihood contribution $L_i^c = L_i^c(\alpha_i, \alpha_i^R, \alpha_i^2, \alpha_i^3)$ given $(\alpha_i, \alpha_i^R, \alpha_i^2, \alpha_i^3)$ can be computed straightforwardly. We present it in detail since this helps to understand the nature of the model; it is

[6] This point is also made by Revelt and Train (1998) who show that adding unobserved heterogeneity to a multinomial logit model breaks the independence of irrelevant alternatives property.

essentially a panel data version of a model with endogenous regime switching and unobserved regimes (see, e.g., Quandt and Ramsey, 1978):[7]

$$L_i^c(\alpha_i,\alpha_i^R,\alpha_i^2,\alpha_i^3)=\prod_{t=1}^{T}L_{i,t}^c(\alpha_i,\alpha_i^R,\alpha_i^2,\alpha_i^3) \tag{8}$$

with:

$L_{i,t}^c(\alpha_i,\alpha_i^R,\alpha_i^2,\alpha_i^3)=P(D_{i,t}=2\,|\,x_{i,t},\alpha_i^2,\alpha_i^3)$ if $y_{i,t}$ is not reported

$$L_{i,t}^c(\alpha_i,\alpha_i^R,\alpha_i^2,\alpha_i^3)=P(D_{i,t}=1\,|\,x_{i,t},\alpha_i^2,\alpha_i^3)P(R_{i,t}=1\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}-0.5<y_{i,t}^*\le y_{i,t}+0.5\,|\,x_{i,t},\alpha_i)$$
$$\text{if } y_{i,t}\in\{0,1,...,100\} \text{ and } y_{i,t}\notin\{5,10,15,....,100\}$$

$$L_{i,t}^c(\alpha_i,\alpha_i^R,\alpha_i^2,\alpha_i^3)=P(D_{i,t}=1\,|\,x_{i,t},\alpha_i^2,\alpha_i^3)[P(R_{i,t}=1\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}-0.5<y_{i,t}^*\le y_{i,t}+0.5\,|\,x_{i,t},\alpha_i)+$$
$$+P(R_{i,t}=2\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}-2.5<y_{i,t}^*\le y_{i,t}+2.5\,|\,x_{i,t},\alpha_i)] \text{ if } y_{i,t}\in\{5,15,35,45,55,65,85,95\}$$

$$L_{i,t}^c(\alpha_i,\alpha_i^R,\alpha_i^2,\alpha_i^3)=P(D_{i,t}=1\,|\,x_{i,t},\alpha_i^2,\alpha_i^3)[P(R_{i,t}=1\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}-0.5<y_{i,t}^*\le y_{i,t}+0.5\,|\,x_{i,t},\alpha_i)+$$
$$+P(R_{i,t}=2\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}-2.5<y_{i,t}^*\le y_{i,t}+2.5\,|\,x_{i,t},\alpha_i)$$
$$+P(R_{i,t}=3\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}-5<y_{i,t}^*\le y_{i,t}+5\,|\,x_{i,t},\alpha_i)] \text{ if } y_{i,t}\in\{10,20,30,40,60,70,80,90\}$$

$$L_{i,t}^c(\alpha_i,\alpha_i^R,\alpha_i^2,\alpha_i^3)=P(D_{i,t}=1\,|\,x_{i,t},\alpha_i^2,\alpha_i^3)[P(R_{i,t}=1\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}-0.5<y_{i,t}^*\le y_{i,t}+0.5\,|\,x_{i,t},\alpha_i)+$$
$$+P(R_{i,t}=2\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}-2.5<y_{i,t}^*\le y_{i,t}+2.5\,|\,x_{i,t},\alpha_i)+$$
$$+P(R_{i,t}=4\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}-12.5<y_{i,t}^*\le y_{i,t}+12.5\,|\,x_{i,t},\alpha_i)] \text{ if } y_{i,t}\in\{25,75\}$$

$$L_{i,t}^c(\alpha_i,\alpha_i^R,\alpha_i^2,\alpha_i^3)=P(D_{i,t}=1\,|\,x_{i,t},\alpha_i^2,\alpha_i^3)[P(R_{i,t}=1\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}^*\le 0.5\,|\,x_{i,t},\alpha_i)+$$
$$+P(R_{i,t}=2\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}^*\le 2.5\,|\,x_{i,t},\alpha_i)+P(R_{i,t}=3\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}^*\le 5\,|\,x_{i,t},\alpha_i)+$$
$$+P(R_{i,t}=4\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}^*\le 12.5\,|\,x_{i,t},\alpha_i)+P(R_{i,t}=5\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}^*\le 25\,|\,x_{i,t},\alpha_i)] \text{ if } y_{i,t}=0$$

$$L_{i,t}^c(\alpha_i,\alpha_i^R,\alpha_i^2,\alpha_i^3)=P(D_{i,t}=1\,|\,x_{i,t},\alpha_i^2,\alpha_i^3)[P(R_{i,t}=1\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}^*>99.5\,|\,x_{i,t},\alpha_i)+$$
$$+P(R_{i,t}=2\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}^*>97.5\,|\,x_{i,t},\alpha_i)+P(R_{i,t}=3\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}^*>95\,|\,x_{i,t},\alpha_i)+$$
$$+P(R_{i,t}=4\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}^*>87.5\,|\,x_{i,t},\alpha_i)+P(R_{i,t}=5\,|\,x_{i,t},\alpha_i^R)P(y_{i,t}^*>75\,|\,x_{i,t},\alpha_i)] \text{ if } y_{i,t}=100$$

$$L_{i,t}^c(\alpha_i,\alpha_i^R,\alpha_i^2,\alpha_i^3)=P(D_{i,t}=1\,|\,x_{i,t},\alpha_i^2,\alpha_i^3)[P(R_{i,t}=1\,|\,x_{i,t},\alpha_i^R)P(49.5<y_{i,t}^*\le 50.5\,|\,x_{i,t},\alpha_i)+$$
$$+P(R_{i,t}=2\,|\,x_{i,t},\alpha_i^R)P(47.5<y_{i,t}^*\le 52.5\,|\,x_{i,t},\alpha_i)+P(R_{i,t}=3\,|\,x_{i,t},\alpha_i^R)P(45<y_{i,t}^*\le 55\,|\,x_{i,t},\alpha_i)+$$
$$+P(R_{i,t}=4\,|\,x_{i,t},\alpha_i^R)P(37.5<y_{i,t}^*\le 62.5\,|\,x_{i,t},\alpha_i)+P(R_{i,t}=5\,|\,x_{i,t},\alpha_i^R)P(25<y_{i,t}^*\le 75\,|\,x_{i,t},\alpha_i)]$$
$$+P(D_{i,t}=3\,|\,x_{i,t},\alpha_i^2,\alpha_i^3) \text{ if } y_{i,t}=50$$

[7] This likelihood contribution is for a respondent who gets the subjective probability question in each wave. $L_{i,t}^c$ is replaced by 1 if *i* does not participate or is not asked the question in wave *t*.

All probabilities in these expressions are either univariate cumulative normal probabilities or multinomial logit probabilities and, therefore, easy to compute.

The unconditional likelihood contribution of respondent i is the expected value of the conditional likelihood over the unobserved heterogeneity terms. Since $(\alpha_i, \alpha_i^R, \alpha_i^2, \alpha_i^3)$ can be written as Λu where u is a vector of six independent standard normal random variables, we can rewrite the unconditional likelihood contribution as:

$$L_i = \int_{\mathbb{R}^4} L_i^c(\Lambda u)\varphi(u_1)...\varphi(u_4)\mathrm{d}u \,. \tag{9}$$

Here φ denotes the density of the standard normal distribution. To avoid numerical integration in five dimensions, the integral is replaced by a simulated mean:

$$SL_i = \frac{1}{M}\sum_{r=1}^{M} L_i^c(\Lambda u^r)\,, \tag{10}$$

where $u^1,...,u^M$ are simulated vectors with components drawn from independent standard normal distributions. To reduce the variance induced by the simulations, we used Halton draws to generate the u^r (see, e.g., Train, 2003). If M tends to ∞ at a fast enough rate, the simulated maximum likelihood estimator is asymptotically equivalent to exact maximum likelihood (see, e.g., Hajivassiliou and Ruud, 1994).[8]

The estimated model parameters can be used to disentangle genuine 0, 50 and 100 answers from rounded and focal point answers. For example, the observed zeros can be genuine zeros that arise because of censoring of a negative value of $y_{i,t}^*$, or they can be rounded zeros, e.g. if $y_{i,t}^* < 12.5$ and there is rounding to multiples of 25. The observed

[8] We found that the results were robust to the number and nature of the Halton draws. The results in the paper are based upon 20 Halton draws for each respondent.

50s can be almost exact 50s (if $R_{i,t} = 1$), they can be rounded 50s (e.g., if $R_{i,t} = 5$ and $25 < y^*_{i,t} \leq 75$, but also if $R_{i,t} = 2$ and $47.5 < y^*_{i,t} \leq 52.5$, etc.), or they can be "50/50" answers that have no relation with $y^*_{i,t}$ (if $D_{i,t} = 3$). Once the model is estimated we can predict the probabilities of all of these types of responses, which will (if the model is correctly specified) add up to the observed fraction of 50 percent answers in the data.

Identification of the rounding probabilities intuitively relies on the sizes of the peaks in the observed frequency distribution: The fact that we observe few probabilities that are not multiples of 5 (for a group with certain characteristics) implies that (for that group) the probability that $R_{i,t} = 1$ is small; Having more multiples of 10 than other multiples of 5 determines the relative magnitudes of the probabilities that $R_{i,t} = 2$ and $R_{i,t} = 3$, etc.; the probability that $R_{i,t} = 5$ is determined by the difference between the fraction of zeros and 100-s in the data and the fraction implied by a censored regression model and the other types of rounding. The probability of a focal point 50/50 ($D_{i,t} = 3$) is determined by the difference between the observed fraction of 50-s and the fraction of 50-s predicted by a model with rounding only and no "50/50" answers.

4. Data and Description of Variables

We use data from the Health and Retirement Study (HRS) for 1994-2010. [9] The HRS is a biennial survey that was started in 1992 with a national sample of 7,600 households

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[9] See Juster and Suzman (1995) and http://hrsonline.isr.umich.edu. The HRS is sponsored by the National Institute of Aging and conducted by the University of Michigan. We use the public use data files produced by the RAND Center for the Study of Aging (Version L and enhanced fat files).

with at least one individual born between 1931 and 1941. The HRS collects information in a variety of areas, including socio-economic status, demographics, and health. We use the original HRS cohort born between 1931 and 1941 and one additional birth cohort added in 1998, the so-called War Babies (WB), born between 1942 and 1947, and their spouses. We restrict out sample to individuals who are at least 50 years old. Tables A1 in the appendix gives an explanation of the covariates used in the estimation and summary statistics for the estimation sample.

Subjective Probabilities

Respondents are asked a variety of subjective probability questions. For our analysis, we use six different probabilities questions that were asked over many waves and for which the wording is (almost) unchanged:

- Stock market expectations;
- Expectations to live to 75 and more;
- Expectations of working full-time after reaching age 62;
- Expectations of health limiting work during the next 10 years;
- Expectations of leaving a bequest of $10,000 or more;
- Expectations of receiving an inheritance.

The respondents could give any number between 0 and 100, or answer “don’t know” or “refuse”. More details on the questions can be found in the online appendix.

Table 1 shows the observed response patterns for the six questions for 2002 (see also the histograms in Figures A1-A6 in the online appendix). The fraction of “don’t know” / “refuse” answers is rather small except for the question about the stock market, which has an item nonresponse rate of 16.1%, perhaps because many respondents are not familiar with financial markets. The percentage of 50% answers is much larger for the questions about living to age 75, the stock market, and a work limiting health condition than for the other three questions, suggesting that focal 50/50 answers might be a problem with these questions in particular. For all questions, there is clear heaping at multiples of 5, and even more at multiples of 10, 25, and 50. While heaping at 50 may also be due to focal answers ($D_{i,t} = 3$ in the model of Section 3), heaping at multiples of 5, 10 and 25 must be due to rounding. The responses to the question on work related health not only show a large frequency at 50%, but also relatively low frequencies at 0% and 100%, suggesting that rounding to multiples of 50 plays a limited role. It could mean that the distribution of genuine probabilities has a large density around 50 percent, but it is more likely that some of the "50 percent" answers are focal 50/50s.

Covariates

Which covariates may be associated with item nonresponse, focal point answers, or rounding was already discussed in Section 2. In our models we include age, gender, race, education, marital status, and health, which all might influence each of the five steps through their effects on knowledge, preferences, and response scales (Cao and Hill, 2005; Bassett and Lumsdaine, 2001). We also include an index of cognitive ability. Following the existing literature, we proxy cognitive ability with answers to immediate word recall questions (see, for example, Cao and Hill, 2005, or van Soest and Hurd, 2008). As of 1996, respondents were given 10 words and immediately asked to recall these words. In 1994, 20 words were given. To make the two tests comparable and to account for possible learning between waves, we use the percentile of the fraction of the words recalled within a wave and cohort, rather than the fraction of words recalled.[10] Additional variables that may be specifically important for some or all of the probability questions under consideration include:

- Income and wealth[11] (for all questions – these variables directly influence bequest possibilities, are correlated with parental wealth to be inherited, affect the retirement age, may drive knowledge about the stock market, and are associated with life expectancy, health, type of work and job characteristics);
- Effort and stress at the current job (main equations of work-related questions only);
- Whether the respondent is the financial respondent of the household (for the bequest, inheritance and stock market questions);
- Whether the respondent has health insurance (for the work related questions in the main equations - since health insurance often comes with the job);
- Whether the respondent's parents are alive[12] (for all questions except stock market expectations, since it is correlated with life expectancy, influences the possibility of receiving an inheritance and may therefore also affect wealth and the probability to leave a bequest; it may also affect labor market participation because of the need to provide informal care (Heitmueller, 2007).

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[10] We thank Patty St. Clair for bringing this pattern of the data to our attention. We used the HRS imputations for missing values and deleted observations with missing values for 2010 (101 person-wave observations) for which imputations were not yet available.

[11] We use the RAND model-based imputations for missing observations of income and wealth.

[12] This variable is set to zero if missing (between 172 and 286 observations per wave).

- Whether the respondent has children[13] (for all questions except stock market expectations, since children may affect life expectancy, bequests often go to the children, family size is correlated across generations and influences the probability of inheritance, and the presence of grandchildren may affect the value of leisure);

We use observations on 13,738 individuals after dropping respondents with only one observed wave or missing information on education (31). We dropped observations in a specific wave if information on health (48 observations), marital status (81), wealth (3), or cognition (101) was missing. This resulted in 90,707 observations in total.

On average, the individuals in our sample are 63 years old; the majority is female, and most of them are married and have children. Many of the explanatory variables are potentially endogenous - to check whether our main results are sensitive to including these variables, we also estimated specifications without any covariates. This hardly changes our results; see, for example, Tables 2 and 3 below.

5. Results

We first present simulation results for estimated model specifications without any covariates to give an impression of the importance of rounding and focal point 50/50 answers.[14] Table 2 shows the simulated probabilities for each type of response for each of the six questions for the 2002 wave (they are very similar to those for the other waves). Simulated item nonresponse rates are in line with the raw data (cf. Table 1),

[13] We also experimented with the number of children but this did not improve the results. When missing, the variable was imputed from the previous or consecutive wave, and set to 0 if those were also missing (between 0 and 160 observations per wave).

[14] Estimation results for these specifications are available upon request.

with the highest rate by far for the stock returns question. For the inheritance and bequest expectations, 50 percent answers are related to rounding while focal 50/50 answers hardly play a role: the estimated probabilities of a focal 50/50 are 0.4% and 0.05%. The focal 50/50 probability is larger for the questions on working after reaching age 62 (4.4%), survival until age 75 (9.7%), and stock returns (13.8%), and quite substantial for the question on work related health (22.3%). This corresponds to what we saw in Section 3: the work related health question has many more 50% answers and relatively few 0 or 100% answers, and this cannot be explained by rounding only.

The opposite pattern is observed for extreme rounding: rounding to the nearest multiple of 50 is common for the inheritance and bequest questions, less common for the questions on working after age 62 and survival until age 75, and does not occur at all for the questions on work related health or stock returns. Rounding to multiples of 10 is the most common form of rounding for all questions, in line with the strong heaping at multiples of 10 in Table 1.

In the remainder we focus on the estimation and simulation results for the complete models with covariates and unobserved heterogeneity. Table 3 shows the simulated probabilities for the 2002 wave for each type of response, similar to Table 2. (They are again similar to those for the other waves although the differences are larger than in Table 2, mainly due to the (sometimes significant) time dummies.) The results generally correspond to those in Table 2. Except for work limitations and stock returns, the majority of 50 percent-answers (cf. Table 1) are explained by rounding and not by focal 50/50 answers reflecting complete uncertainty. For all questions, rounding to the nearest multiple of 10 is most frequent, followed by rounding to multiples of 25. As argued in Section 2, crude rounding to multiples of 25 or 50 may also reflect uncertainty, so that the small focal 50/50 probabilities do not imply that uncertainty does not affect the numerical answers. The difference is that rounded answers, even to a multiple of 50, still carry some information: a rounded 50 percent answer refers to a true probability between 25 and 75 percent, while a focal 50/50 says nothing about the true probability.[15] If we add up the probabilities of item non-response, focal 50/50, and rounding to the nearest multiple of 50 percent, we find the largest sum for the stock return question (this conclusion does not change if rounding to a multiple of 25 is also considered crude rounding) and the second largest for the work limitations probability (though this falls to third place if rounding to a multiple of 25 is added). This is in line with the predictions in Section 2 where these two questions were identified as the most difficult ones. The large sum for the survival probability is somewhat surprising.

The inheritance question shows more precise answers and less rounding to multiples of 10 or 25 than the other questions. The response patterns for the work limitations and stock returns questions deviate from the others in the sense that there is a substantial number of focal 50/50 answers but no rounding to multiples of 50, as we saw in Table 2. On the other hand, the chances of rounding to multiples of 5, 10, or 25 are of the same order of magnitude as for the other questions.

The estimates of the rounding equations can be seen in Table 4. As discussed in Section 2, the relations with the covariates may reflect differences in epistemic uncertainty or a general tendency of the respondent to give imprecise answers. Many

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[15] In some waves, follow up questions were asked after a 50 percent answer to the stock return or survival until age 75 question, where respondents could choose between "equally likely" and "unsure" or "one cannot know" (see Hurd, 2009, and Hudomiet *et al*., 2011). Only a minority chose "equally likely". Our results can be reconciled with this if crude rounding often reflects uncertainty, leading to the "unsure" answer in the follow up question.

coefficients are similar across questions. For example, there is less rounding the higher the education level and the better cognition is, possibly because the respondents who are more skilled give more precise answers. Blacks are generally less likely to round than whites, but the difference between Hispanics and non-Hispanics varies across questions. Higher income is related to less rounding for the question about leaving a bequest, probably because of lower uncertainty. Age is positively related to rounding, except for the inheritance question, probably because uncertainty about receiving an inheritance falls with age. The estimated standard deviations of the individual effects imply that 18 to 49 percent of the unsystematic variation is captured by unobserved heterogeneity (and the remainder by error terms, with variance normalized to 1).

Tables 5 and 6 present the results of the multinomial logit part of the model explaining the choice between giving a (rounded) numerical answer (the benchmark), answering “don’t know” or “refuse” (nonresponse), or giving a focal 50/50 answer. Most of the results in Table 5 are in line with the prediction from Section 2 that lower skills or more uncertainty increases item nonresponse. Higher education, higher income, and better cognition are related to a lower probability of nonresponse. Financial respondents are more likely to respond to the questions about stock returns, inheritance and bequests.[16] Other results cannot be explained in this way and may reflect cultural differences across socio-economic groups. For example, the nonresponse probability increases significantly with age for five out of the six questions. Blacks and Hispanics are more likely to not respond than whites. The effect

[16] This is similar to the findings of Cao and Hill (2005) who analyze item nonresponse to questions about assets in the 2000 wave of the HRS.

of wealth is inconsistent across questions – wealthier households respond significantly less often to the bequest question, but more often to several other questions.

Table 6 shows the results for the tendency to give a focal 50/50 answer.[17] The pattern is less consistent across questions than in Table 5 and less in line with the predictions in Section 2. There is some evidence of a negative effect of education for most questions. For example, for the work limitations question with the largest 50/50 probabilities, we find a strong and significant negative effect of education. Compared to otherwise similar respondents with high school education, respondents with a college degree are about 8 percentage points less likely to give a focal 50/50 answer.[18] On the other hand, our measure of cognition is never statistically significant. For the inheritance question and (in particular) the bequest questions the focal 50/50 probabilities seem too small to get meaningful estimates (cf. Table 3).

Tables 7-9 show the estimation results of the unobserved true subjective probabilities (equation (1) in Section 3) and compare them to estimates from random-effects (RE) tobit estimations that do not account for rounding or focal 50/50 answers and assume item nonresponse is random conditional upon the covariates. In general, the results of the estimates for the full model are qualitatively similar to those of the RE

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[17] For the bequest and inheritance questions, estimated focal 50/50 probabilities are quite small (cf. Table 3) or even zero for some groups, leading to estimates of $-\infty$ on some coefficients. For the bequest question, we also had to impose some exclusion restrictions to obtain convergence.

[18] Using the parameter estimates in Tables 5 and 6, the estimated marginal effect of changing from high school to college education, keeping other variables constant, is given by -0.533 P(50/50) (1-P(50/50) + 0.750 P(50/50) P(nonresponse). For the average probabilities of a focal 50/50 and item nonresponse in Table 3, this gives -0.533*0.220*(1-0.220)+0.750*0.220*0.045= -0.083.

tobit models. For most covariates, the effects are somewhat larger according to the complete model based estimates than in the RE tobit specifications but signs and significant levels hardly differ. This seems reassuring for researchers who take the reported probabilities for granted, implying that not incorporating rounding, focal 50/50 answers or item nonresponse hardly affects the qualitative conclusions concerning the determinants of the subjective probabilities. We will not discuss the estimates in detail since they are in line with existing studies using standard models (see Section 1).

The bottom parts of Tables 7-9 show the estimated standard deviations of the unobserved heterogeneity terms and the idiosyncratic error. These estimates are very accurate, implying that differences between the two models are always significant, even though the magnitudes of the estimates are often similar. The largest differences are found for the bequests question. Reporting behavior apparently captures a large part of the unexplained variation here, so that incorporating this in the full model reduces the remaining part ascribed to unobserved heterogeneity and error terms. The share of unexplained variation ascribed to unobserved heterogeneity rather than error terms is smallest for the questions on stock returns and work limitations, in line with the notion that these are the most difficult questions and therefore have the highest noise level, even when purged for the three forms of reporting behavior that we consider.

Table 10 shows the correlation matrices of the four individual effects in the models for all six probabilities. All of these 36 unobserved heterogeneity terms are statistically significant. Since (time persistent) uncertainty about the true probability drives all three forms of reporting behavior (rounding, item nonresponse, and focal 50/50 answers), we expected the three unobserved heterogeneity terms to be positively correlated. This is indeed the case in 14 out of 18 cases. Respondents who tend to not respond, therefore, also typically tend to give a focal 50/50 answer or to round to multiples of 50 or 25. The few negative signs could point at substitution effects: some respondents choose to not respond, while others give a focal 50/50 when they are uncertain about the true probability. Existing studies (Section 2) do not explain why negative signs are found for some probabilities and forms of reporting behavior and not for others.

To investigate whether incorporating reporting behavior in the model affects conclusions about the marginal distributions of the subjective probabilities (not conditioning on covariates), we simulated the distributions of the true probabilities $y_{i,t}^{T}$ (see Section 2) according to the full model and according to the RE Tobit model that does not account for reporting behavior. Table 11 presents the means and standard deviations of these simulated distributions as well as, for comparison, the sample means and standard deviations in the actual data (excluding observations with item nonresponse). The means and standard deviations for the full model and the RE Tobit model are surprisingly close to each other in most cases, and the differences are generally of the same order of magnitude as the differences between simulated and sample statistics. This suggests that, though reporting behavior plays a significant role, ignoring it does not induce a large bias on the estimated means and standard deviations of the probabilities considered. Of course, this result may be specific to the six probabilities we consider. For example, if we have small average probabilities but a large probability of a focal 50/50, we would expect that the focal 50/50 answers lead to an overestimate of the average of the true probabilities. But amongst the six probabilities we consider, only the average probability of receiving an inheritance is rather small, and there the estimated focal 50/50 probability is less than 0.01 (Table 3).

6. Conclusions

Answers to expectation questions are used more and more frequently to understand individual behavior and outcomes. How individuals respond to this type of questions is not fully understood. In particular, heaping at 50/50 has led to some doubt on the quality of this kind of data. Three types of "reporting behavior" can be distinguished that preclude reporting the true subjective probabilities: rounding, focal 50/50 answers, and item nonresponse. In this paper, we develop a random-effects panel data model for the true probabilities and these three types of reporting behavior of response to questions about subjective probabilities, explicitly accounting for the possibility of focal point answers of 50, rounding, and item nonresponse. Applying the model to six subjective probabilities in the Health and Retirement Study, we assess persistence of reporting behavior over time and analyze how the importance of each type of reporting behavior varies with the nature of the question and with respondent characteristics. Moreover, comparing with a model not incorporating reporting behavior, we assess the importance of taking reporting behavior into account.

We find that some subjective probabilities are much more affected by all three types of reporting behavior than others. The questions on receiving an inheritance and leaving a bequest are least affected. The psychological arguments for rounding, focal 50/50 answers, and item nonresponse are similar. They lead to the prediction that the question on expected stock market returns, something many respondents are not familiar with and over which respondents have no control, induces a lot of reporting behavior. This is confirmed by our analysis. Moreover, we find a substantial share of focal 50/50 answers in the question on work limitations, which may be explained by the fact that the outcome referred to is not unambiguously defined. As predicted, rounding and nonresponse are negatively related to cognitive skills and education level, but this pattern is less consistent for focal 50/50 answers. The estimated unobserved heterogeneity structure shows that the three types of reporting behavior are rather persistent over time and are generally positively correlated, in line with the notion that they are all indexes of (epistemic) uncertainty concerning the true probability. Rounding and nonresponse are also strongly related to other socio-demographic variables, including race and ethnicity. When comparing the results of our model with those of a random-effects tobit model not incorporating reporting behavior, we find that signs and significance levels are very similar, but the size of the effects of socio-demographic variables on the expected probabilities often appear to be somewhat overestimated if reporting behavior is ignored. Moreover, ignoring reporting behavior only leads to modest biases in the estimated means and standard deviations of the true probabilities. These results seem to be good news for applied researchers who want to analyze subjective probabilities using standard models. These results might, however, be specific to the six probabilities we have analyzed. The modeling framework we have introduced can be used to analyze whether they also apply more generally.

Another research direction investigates how subjective probabilities can be elicited in an alternative way in order to reduce rounding and focal answers, exploiting, for example, graphical devices that become possible with Internet interviewing. Results of Bruine de Bruin et al. (2002), for example, suggest that asking respondents to select a point on a ruler with a continuous scale from 0 until 100 helps to reduce 50/50 answers. While this may reduce the reporting problems in future surveys, the subjective probabilities in the HRS will remain the main data source on subjective probabilities for the years to come, particularly for longitudinal analysis exploiting the panel dimension. Rounding, item nonresponse and focal 50/50-s have led to doubts about the quality of these data. We hope that our analysis has shown that handling these reporting problems is feasible and worthwhile, further strengthening the value of subjective probabilities for economic research.

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APPENDIX

Table A1 Variable Definitions and Summary Statistics [a]

Variable Name	Means	Description
Age	63.45	
	(6.89)	
Male	0.43	
Black	0.15	
Hispanic	0.08	
Education		
Less than HS	0.22	
HS	0.37	
Some College	0.21	
College	0.20	
Not Married	0.27	neither married nor partnered
Child	0.94	at least one child
Parent alive	0.27	any of the parents is alive
Financial Respondent	0.67	
Bad Health	0.25	self-reported health status fair or poor
Cognition	0.42	Percentile of word recall by cohort/100
	(0.29)	
Log of income	10.26	Log of real total household income in $2002 divided by
	(1.35)	the square root of the household size [b]
Log of wealth	10.58	Log of real total household wealth in $2002 divided by the
	(4.58)	square root of the household size [b]
Insured	0.81	covered by health insurance (by government, current or previous employer, other)
Work	0.45	currently working for pay
Effort	0.40[c]	current job requires lots of physical effort or lifting heavy loads or stooping, kneeling, or crouching all, almost all, or most of the time
Stress	0.52[c]	current job involves a lot of stress all, almost all, or most of the time

[a] *All years. Standard deviations shown in parentheses except for dummy variables.*

[b] *Log is defined as log(x+1) if x >=0 and –log(1-x) if x<0.*

[c] *For those working only.*

Table 1 Response Patterns by Probability Question – 2002 (in %)*

Answer	Liv75	Stocks	Worklm	Work62	Beq10	Inher
Don't know/ Refuse	4.73	16.12	4.33	1.24	3.36	2.80
0%	3.68	6.93	10.64	19.82	13.65	67.49
50%	22.24	25.75	31.84	14.34	7.49	4.71
100%	17.83	4.33	3.16	20.05	43.79	5.84
Other multiples of 10	36.06	33.18	37.08	32.17	23.52	12.96
Multiples ending in 5	14.51	13.11	12.37	11.30	6.65	4.46
Other	0.95	0.58	0.58	1.09	1.53	1.73
N	6,708	4,645	4,275	2,664	10,554	10,554

** Working sample. Totals may not add up to 100% because of rounding.*

Table 2 Simulated Probabilities for 2002: Model without Regressors

	Liv75	Stocks	Worklm	Work62	Inher	Beq10
Rounding to a multiple of						
1	1.96	1.18	1.23	2.91	9.66	4.68
5	14.68	11.40	11.53	15.76	25.37	14.32
10	38.65	43.56	43.70	48.72	38.33	48.02
25	19.63	13.59	16.60	18.13	8.82	10.93
50	10.04	0.00	0.00	9.01	14.77	18.28
Nonresponse	5.31	16.51	4.66	1.08	2.64	3.72
50/50	9.74	13.76	22.27	4.41	0.40	0.05
N	6,708	4,645	4,275	2,664	10,554	10,554

Table 3 Simulated Probabilities for 2002: Complete Model

	Liv75	Stocks	Worklm	Work62	Inher	Beq10
Rounding to a multiple of						
1	2.17	0.88	1.30	3.58	11.81	5.07
5	15.89	9.66	11.88	17.39	28.53	15.29
10	39.01	42.98	44.11	47.19	38.91	49.16
25	18.32	15.54	16.41	15.69	8.01	10.67
50	12.60	0.00	0.00	11.16	8.70	15.82
Nonresponse	4.99	16.04	4.49	1.24	2.98	3.72
50/50	7.02	14.90	21.81	3.74	0.99	0.28
N	6,708	4,645	4,281	2,664	10,554	10,554

Table 4 Estimation Results for Rounding Equations*

	Liv75	Stocks	Worklm	Work62	Inher	Beq10
Age/100	-0.052	0.187	1.361	2.780	-1.192	1.256
	(-0.21)	(0.96)	(4.04)	(4.91)	(-3.56)	(6.45)
Male	0.007	0.005	-0.001	-0.064	-0.103	-0.106
	(0.30)	(0.20)	(-0.03)	(-1.59)	(-2.72)	(-4.33)
Black	0.078	-0.246	-0.323	-0.115	-0.234	-0.050
	(3.08)	(-7.50)	(-6.67)	(-2.38)	(-4.75)	(-1.86)
Hispanic	0.125	-0.132	-0.251	-0.130	-0.027	0.230
	(3.62)	(-2.59)	(-3.23)	(-1.89)	(-0.38)	(6.45)
Education						
Less than HS	0.169	-0.037	0.032	0.224	-0.114	0.207
	(6.60)	(-1.12)	(0.63)	(4.24)	(-2.28)	(7.88)
Some college	-0.220	-0.015	-0.058	-0.072	-0.084	-0.155
	(-8.84)	(-0.53)	(-1.42)	(-1.67)	(-2.05)	(-5.59)
College	-0.424	-0.079	-0.201	-0.374	-0.214	-0.547
	(-15.23)	(-2.53)	(-5.20)	(-8.02)	(-5.11)	(-18.56)
Not married	-0.013	0.035	0.024	0.083	-0.094	0.001
	(-0.48)	(0.99)	(0.54)	(1.65)	(-1.82)	(0.04)
Not married *	0.096	0.075	-0.040	-0.057	0.090	0.164
male	(2.15)	(1.41)	(-0.52)	(-0.68)	(1.17)	(3.66)
Child	0.033	-	0.052	0.065	0.023	-0.052
	(0.88)		(0.80)	(0.10)	(0.35)	(-1.34)
Parent alive	-0.032	-	-0.036	0.029	0.125	-0.059
	(-1.64)		(-1.16)	(0.86)	(3.81)	(-2.66)
Financial	-	0.044	-	-	-0.009	-0.014
respondent		(1.65)			(-0.25)	(-0.59)
Bad health	0.088	0.017	0.026	0.059	0.076	0.088
	(4.05)	(0.63)	(0.51)	(1.23)	(1.87)	(4.09)
Cognition	-0.133	-0.062	-0.061	-0.183	-0.025	-0.160
	(-3.94)	(-1.50)	(-1.08)	(-3.10)	(-0.45)	(-4.63)
Log of income /100	-0.2482	1.340	-0.229	-0.867	-0.784	-5.121
	(-0.37)	(1.22)	(-0.14)	(-0.57)	(-0.60)	(-7.24)
Log of wealth /100	-0.414	0.468	0.381	0.124	1.145	0.278
	(-2.23)	(1.73)	(0.93)	(0.31)	(3.05)	(1.40)
Work	0.009	0.093	-	-	0.003	0.005
	(0.44)	(3.76)			(0.10)	(0.26)
σ(α)	0.574	0.464	0.473	0.602	0.971	0.671

** t-values shown in parentheses. Intercept and time dummies included but not reported.*

Table 5 Estimation Results for Random Effects Multinomial Logit: Nonresponse*

	Liv75	Stocks	Worklm	Work62	Inher	Beq10
Age/100	3.207	3.005	4.260	2.029	2.515	4.811
	(4.57)	(7.78)	(4.70)	(0.87)	(4.66)	(11.50)
Male	-0.346	-1.074	-0.135	-0.330	-0.399	-0.438
	(-5.47)	(-18.51)	(-1.43)	(-1.90)	(-5.58)	(-7.93)
Black	1.118	0.457	0.626	0.718	0.992	0.776
	(18.22)	(7.36)	(6.24)	(4.23)	(15.16)	(13.23)
Hispanic	1.207	1.110	0.919	1.329	0.202	0.458
	(15.85)	(13.94)	(6.97)	(6.96)	(2.37)	(6.57)
Education						
Less than HS	0.902	0.673	0.542	0.559	0.565	0.558
	(14.03)	(11.38)	(4.84)	(3.30)	(8.21)	(10.17)
Some college	-0.302	-0.488	-0.089	-0.210	-0.027	-0.204
	(-4.02)	(-7.88)	(-0.89)	(-1.09)	(-0.33)	(-3.19)
College	-0.452	-0.977	-0.764	-0.536	-0.001	-0.243
	(5.38)	(-14.32)	(-6.33)	(-2.05)	(0.02)	(-3.71)
Not married	-0.022	0.158	0.182	0.103	-0.101	-0.236
	(-0.32)	(2.45)	(1.64)	(0.58)	(-1.18)	(-3.60)
Not married * male	0.392	0.350	0.044	0.357	0.644	0.497
	(3.33)	(3.54)	(0.24)	(1.19)	(5.18)	(5.06)
Child	0.071	-	0.165	-0.104	-0.250	-0.251
	(0.64)		(0.96)	(-0.38)	(-2.38)	(-3.03)
Parent	-0.040	-	0.033	0.312	0.254	-0.026
	(-0.75)		(0.40)	(2.35)	(3.97)	(-0.46)
Financial respondent	-	-0.266	-	-	-0.234	-0.311
		(-4.97)			(-3.44)	(-6.07)
Bad health	0.265	0.384	0.098	0.518	0.117	0.218
	(4.78)	(8.74)	(0.89)	(3.50)	(1.88)	(4.55)
Cognition	-0.523	-0.366	-0.163	-0.682	-0.884	-0.706
	(-5.50)	(-4.86)	(-1.21)	(-2.60)	(-8.37)	(-8.59)
Log of income/100	-9.273	-12.639	-11.890	-19.489	-12.480	-11.345
	(-6.87)	(-7.76)	(-4.14)	(-5.45)	(-7.52)	(-8.17)
Log of wealth/100	-0.915	-2.598	-2.287	-0.247	-0.366	1.422
	(-1.90)	(-6.47)	(-2.81)	(-0.17)	(-0.61)	(2.92)
Work	0.206	-0.056	-	-	-0.189	-0.144
	(3.69)	(-1.16)			(-3.00)	(-2.74)
$\sigma(\alpha)$	1.525	1.606	1.507	0.741	1.339	1.729

** t-values shown in parentheses. Intercept and time dummies included but not reported.*

Table 6 Estimation Results for Random Effects Multinomial Logit: 50/50*

	Liv75	Stocks	Worklm	Work62	Inher	Beq10
Age/100	3.746	-0.428	3.434	-18.554	-9.972	-6.012
	(2.84)	(-0.92)	(5.76)	(-4.96)	(-5.84)	(-1.84)
Male	0.011	-0.414	0.020	-0.233	-0.154	-1.022
	(0.10)	(-6.47)	(0.31)	(-1.11)	(-0.88)	(-2.16)
Black	-0.826	-0.310	-0.283	0.689	-0.559	1.025
	(-4.90)	(-3.84)	(-3.43)	(2.97)	(-2.20)	(2.36)
Hispanic	-1.854	-0.233	-0.156	0.816	-∞	-2.093
	(-3.61)	(-1.95)	(-1.36)	(2.63)		(-0.77)
Education						
Less than HS	-0.716	-0.353	0.040	-0.425	0.013	-1.784
	(-4.40)	(4.39)	(0.48)	(-1.32)	(0.05)	(-2.32)
Some college	-0.811	-0.272	-0.153	-0.383	0.253	-0.889
	(-6.66)	(-4.19)	(-2.17)	(-1.53)	(1.55)	(-1.94)
College	-1.166	-0.416	-0.540	-0.220	-0.656	-∞
	(-8.36)	(-5.83)	(-7.16)	(-0.93)	(-3.01)	
Not married	0.001	-0.144	-0.047	-0.903	0.162	-2.389
	(0.00)	(-1.86)	(-0.57)	(-2.38)	(-0.79)	(-3.40)
Not married * male	-0.466	0.224	-0.025	-0.658	-0.624	
	(-1.71)	(1.76)	(-0.19)	(-0.57)	(-1.62)	
Child	0.090	-	-0.066	-0.262	-0.296	0.941
	(0.44)		(-0.58)	(-0.71)	(-1.14)	(0.61)
Parent alive	-0.074	-	-0.186	-0.252	3.463	
	(-0.75)		(-3.34)	(-1.32)	(6.48)	
Financial respondent	-	-0.018	-	-	0.522	
		(-0.30)			(3.07)	
Bad health	-1.023	0.018	-0.123	-0.294	-0.620	-1.353
	(-6.91)	(0.30)	(-1.41)	(-1.00)	(-2.43)	(-2.26)
Cognition	0.211	0.197	-0.084	-0.326	0.188	-0.887
	(1.24)	(2.12)	(-0.87)	(-0.957)	(0.73)	(-1.33)
Log of income/100	-4.079	3.085	-1.429	-1.025	0.719	96.335
	(-1.09)	(1.21)	(-0.53)	(-0.10)	(0.10)	(3.64)
Log of wealth/100	4.590	0.856	-0.515	-2.458	3.971	-15.928
	(2.74)	(1.40)	(-0.74)	(-1.31)	(1.80)	(-6.38)
Work	0.234	0.045	-	-	0.068	0.616
	(2.31)	(0.79)			(0.39)	(1.36)
σ(α)	2.093	1.154	1.198	1.272	1.714	2.539

** t-values shown in parentheses. Intercept and time dummies included but not reported.*

Table 7 Results Main Equation in Full Model & Random Effects Tobits: Probabilities for Living to Age 75 and the Stock Market *

	Liv75		Stocks	
	Full Model	**RE Tobit**	**Full Model**	**RE Tobit**
Age	0.497	0.469	-0.335	-0.284
	(10.58)	(8.79)	(-9.37)	(-8.33)
Male	-3.281	-3.170	8.507	6.867
	(-7.68)	(-5.55)	(16.40)	(14.33)
Black	6.551	8.220	-2.874	-2.614
	(13.04)	(11.20)	(-4.81)	(-4.50)
Hispanic	-5.178	-6.037	-1.491	-1.302
	(-7.19)	(-6.29)	(-1.87)	(-1.65)
Education				
Less than HS	-3.996	-4.546*	-1.602	-1.717
	(-7.72)	(-6.26)	(-2.75)	(-2.94)
Some college	5.446	4.748	4.090	3.244
	(11.15)	(6.98)	(7.41)	(6.31)
College	5.428	5.094	8.266	6.748
	(9.48)	(7.13)	(13.78)	(12.65)
Not married	-0.597	-0.311	0.558	0.443
	(-1.30)	(-0.52)	(0.87)	(0.76)
Not married * male	-2.279	-2.550	-2.493	-2.071
	(-2.84)	(-2.52)	(-2.78)	(-2.35)
Child	0.122	0.028	-	-
	(0.18)	(0.03)		
Parent alive	3.520	3.500	-	-
	(10.57)	(8.83)		
Financial respondent	-	-	1.462	0.932
			(2.97)	(2.06)
Bad health	-13.000	-12.825	-3.801	-3.236
	(-40.17)	(-31.32)	(-8.80)	(-8.03)
Cognition	3.454	3.584	3.087	2.668
	(6.85)	(6.59)	(4.49)	(4.49)
Log of income	0.728	0.738	0.963	0.852
	(7.90)	(6.56)	(6.03)	(5.54)
Log of wealth	0.221	0.216	0.362	0.343
	(7.55)	(5.98)	(9.01)	(8.66)
Work	0.980	0.955	0.224	0.195
	(3.21)	(2.71)	0.53)	(0.52)
Sigma u	23.632	24.520	-15.824	14.153
	(128.90)	(109.42)	(-68.55)	(68.39)
Sigma e	20.967	24.392	25.689	24.678
	(232.76)	(235.82)	(213.38)	(211.38)
N	52,011**		36,729**	

** t-values shown in parentheses. Intercept and time dummies included but not reported.*
*** Excluding item nonresponse.*

Table 8 Results Main Equation in Full Model & Random Effects Tobits: Work-related Probabilities*

	Worklm		Work62	
	Full Model	**RE Tobit**	**Full Model**	**RE Tobit**
Age	0.910	0.783	1.358	1.496
	(13.24)	(13.68)	(9.88)	(9.37)
Male	2.222	1.647	15.202	18.660
	(3.07)	(2.66)	(12.54)	(12.85)
Black	-4.883	-4.472	-12.829	-14.404
	(-5.56)	(-5.63)	(-7.78)	(-7.68)
Hispanic	-1.982	-1.899	0.565	-0.074
	(-1.61)	(-1.76)	(0.25)	(-0.03)
Education				
Less than HS	-1.510	-0.856	-2.780	-3.911
	(-1.63)	(-1.03)	(-1.62)	(-1.94)
Some college	-0.062	-0.881	5.749	6.109
	(-0.08)	(-1.25)	(4.12)	(3.64)
College	0.442	-1.169	6.627	8.080
	(0.50)	(-1.62)	(4.61)	(4.62)
Not married	1.3973	1.258	16.494	18.647
	(1.51)	(1.60)	(11.88)	(11.30)
Not married * male	-2.948	-2.081	-15.523	-18.440
	(-1.99)	(-1.61)	(-6.91)	(-6.61)
Child	1.393	1.131	0.689	1.718
	(1.16)	(1.10)	(0.36)	(0.76)
Parent alive	-2.480	-2.379	2.439	2.782
	(-4.03)	(-4.66)	(2.75)	(2.64)
Bad health	15.462	11.667	-9.958	-10.650
	(18.70)	(15.66)	(-9.09)	(-8.38)
Cognition	-0.786	-0.611	2.667	3.415
	(-0.79)	(-0.76)	(2.01)	(2.30)
Log of income	-0.406	-0.353	-0.921	-1.106
	(-1.48)	(-1.55)	(-2.76)	(-2.70)
Log of wealth	-0.128	-0.105	-0.520	-0.545
	(-1.83)	(-1.72)	(-5.87)	(-5.23)
Insured	0.715	0.841	3.327	3.416
	(1.10)	(1.56)	(3.80)	(3.34)
Effort	2.347	2.065	-0.080	0.222
	(3.95)	(4.11)	(-0.09)	(0.22)
Stress	2.475	1.970	4.070	4.347
	(4.55)	(4.40)	(5.47)	(5.11)
Sigma u	19.116	16.603	44.109	48.074
	(53.26)	(56.95)	(63.93)	(76.50)
Sigma e	28.077	26.565	36.382	42.258
	(146.07)	(154.45)	(105.74)	(126.50)
N	23,417**		24,236**	

** t-values shown in parentheses. Intercept and time dummies included but not reported.*
*** Excluding item nonresponse.*

Table 9 Results Main Equation in Full Model & Random Effects Tobits: Probabilities of Inheritances and Bequests *

	Inher		Beq10	
	Full Model	**RE Tobit**	**Full Model**	**RE Tobit**
Age	-2.307	-2.681	-0.158	-0.087
	(-25.91)	(-21.96)	(-2.77)	(-1.02)
Male	6.402	7.089	13.263	15.836
	(6.13)	(4.72)	(17.75)	(14.29)
Black	-13.386	-14.859	-21.120	-27.496
	(-9.86)	(-7.80)	(-22.69)	(-20.09)
Hispanic	-39.344	-46.902	-12.743	-17.914
	(-21.79)	(-16.95)	(-11.28)	(-10.02)
Education				
Less than HS	-21.841	-25.186	-21.342	-29.554
	(-16.92)	(-12.96)	(-24.48)	(-21.95)
Some college	12.568	16.070	12.246	14.191
	(10.56)	(9.36)	(14.33)	(10.86)
College	21.743	26.871	24.397	26.680
	(16.81)	(15.08)	(25.31)	(19.24)
Not married	-7.107	-7.202	-5.563	-6.961
	(-5.68)	(-4.17)	(-7.35)	(-6.23)
Not married * male	-2.749	-3.848	1.448	2.543
	(-1.37)	(-1.44)	(1.28)	(1.47)
Child	-2.012	-2.449	7.271	7.690
	(-1.20)	(-1.08)	(7.26)	(4.82)
Parent alive	46.544	53.937	0.271	-0.119
	(62.96)	(51.90)	(0.48)	(-0.16)
Financial respondent	-1.607	-1.200	0.956	0.427
	(-1.71)	(-0.89)	(1.45)	(0.45)
Bad health	-6.256	-6.769	-9.291	-10.690
	(-7.16)	(-6.24)	(-18.50)	(-15.67)
Cognition	3.271	3.439	10.694	12.721
	(2.70)	(2.46)	(13.61)	(12.86)
Log of income	1.711	1.645	4.124	4.763
	(6.60)	(4.89)	(26.40)	(20.88)
Log of wealth	0.579	0.619	2.518	2.851
	(6.91)	(5.78)	(60.77)	(42.38)
Work	0.142	2.014	2.003	2.450
	(1.99)	(2.22)	(4.18)	(3.90)
Sigma u	56.259	60.186	41.358	48.308
	(98.92)	(88.43)	(128.14)	(103.06)
Sigma e	47.806	54.793	41.823	51.117
	(159.37)	(153.33)	(269.47)	(217.46)
N	70,183**			87,914**

** t-values shown in parentheses. Intercept and time dummies included but not reported.*
*** Excluding item nonresponse.*

Table 10 Correlation Matrices of Individual Effects

		Probability	Rounding	Nonresponse
Liv75	**Rounding**	-0.269		
	Nonresponse	-0.323	0.362	
	50/50	-0.562	0.546	0.111
Stocks	**Rounding**	0.617		
	Nonresponse	-0.297	-0.030	
	50/50	-0.302	0.560	0.317
Worklm	**Rounding**	0.701		
	Nonresponse	0.037	0.738	
	50/50	0.380	0.528	0.344
Work62	**Rounding**	-0.010		
	Nonresponse	0.179	0.669	
	50/50	0.296	0.273	-0.334
Inher	**Rounding**	0.426		
	Nonresponse	0.147	0.193	
	50/50	0.249	-0.002	0.045
Beq10	**Rounding**	-0.104		
	Nonresponse	-0.258	0.341	
	50/50	-0.492	-0.157	0.816

Note: Standard deviations of the individual effects are given in Tables 4-9.

Table 11 Simulated Distributions of True Probabilities: Full Model and RE Tobit

		Mean	Standard Deviation	N
Liv75	**Full Model**	63.43	27.99	6,708
	RE Tobit	65.52	29.31	6,708
	Sample	66.38	28.11	6,391
Stocks	**Full Model**	43.94	27.98	4,645
	RE Tobit	46.38	27.17	4,645
	Sample	46.50	27.72	3,900
Worklm	**Full Model**	40.07	29.50	4,275
	RE Tobit	40.82	28.23	4,275
	Sample	40.57	26.82	4,090
Work62	**Full Model**	48.33	37.77	2,664
	RE Tobit	45.85	38.98	2,664
	Sample	50.31	38.38	2,631
Inher	**Full Model**	17.11	30.56	10,554
	RE Tobit	15.45	29.99	10,554
	Sample	16.13	31.52	10,259
Beq10	**Full Model**	66,66	37.78	10,554
	RE Tobit	66.63	38.84	10,554
	Sample	69.99	38.24	10,200

Notes:

Full Model and RE Tobit: mean and standard deviations using simulated data on the true probabilities $y_{i,t}^{T}$*, based upon actual data on the covariates, estimated model parameters, and random draws of individual effects and error terms.*

Sample: reported probabilities, excludes observations with item nonresponse (which explains the smaller N).

Material for Online Appendix

Rounding, Focal Point Answers and Nonresponse to Subjective Probability Questions

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Arthur van Soest, Netspar, Tilburg University

APPENDIX

Subjective Probability Questions

We present details on the six subjective probability questions. The first question asks about the stock market from 2002 until 2010. In 2002 and 2004 the question is:

"*We are interested in how well you think the economy will do in the next year. By next year at this time, what is the percent chance that mutual fund shares invested in blue chips stocks like those in the Dow Jones Industrial Average will be worth more than they are today?*"

For later waves, "next year" was replaced by "in the future." In 2002, there are quite a few missings, which according to the HRS is due to an incorrect skip pattern.

The second question we use is asked of respondents of age 65 and under: [19]

"What is the percent chance that you will live to be 75 or more?"

Two questions concern personal financial issues: bequests and inheritances. In 1994 and 1996, the question about bequests is as follows:[20]

[19] We do not use 111 person-wave observations where the respondent was over age 65.

"And what are the chances that you (or your husband/ wife/ partner) will leave an inheritance totaling $10,000 or more?"

From 1998 onwards, the wording of the question is somewhat different:

"Including property and other valuables that you might own, what are the chances that you (and your husband/ wife/ partner) will leave an inheritance totaling $10,000 or more?"

The question about inheritances was asked from 1994 to 2006. The wording of this second question is the same in all waves except for 2006:

"And how about the chances that you will receive an inheritance within the next ten years?"

In 2006, the wording was changed to:

"(Not counting anything you might give or leave to each other,) [what/What] are the chances that you (or your [husband/ wife/ partner]) will receive an inheritance during the next 10 years?"

The final two questions we consider are work related:

"What do you think are the chances that you will work full-time after you reach age 62?"[21]

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[20] If the answer is more than zero, a follow-up question asks about the chances of leaving a bequest of $100,000 or more. We do not discuss the results for this question since the results were unsurprising.

[21] We do not use the follow-up question about the probability of working full-time after age 65.

Except for the year 2006, this question was supposed to be asked only if the respondent was working and less than 62 years old. We, therefore, also deleted the 2006 answers of respondents who were not working or aged 62 or older.

The last question we consider was asked from 1994-2002:

"What about the chances that your health will limit your work activity during the next 10 years?"

This question was only asked if the respondent was currently working. Answers of respondents who already had a work limiting health condition as well as answers given by proxy respondents were dropped.

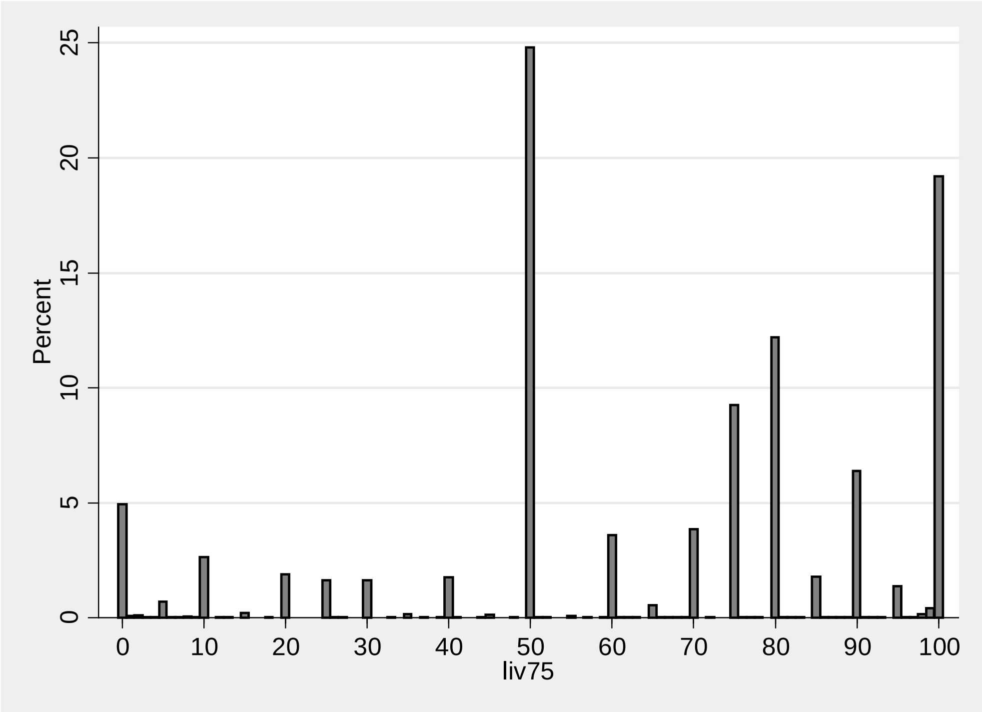

Figure A1 Distribution of Numerical Responses: Survival 75

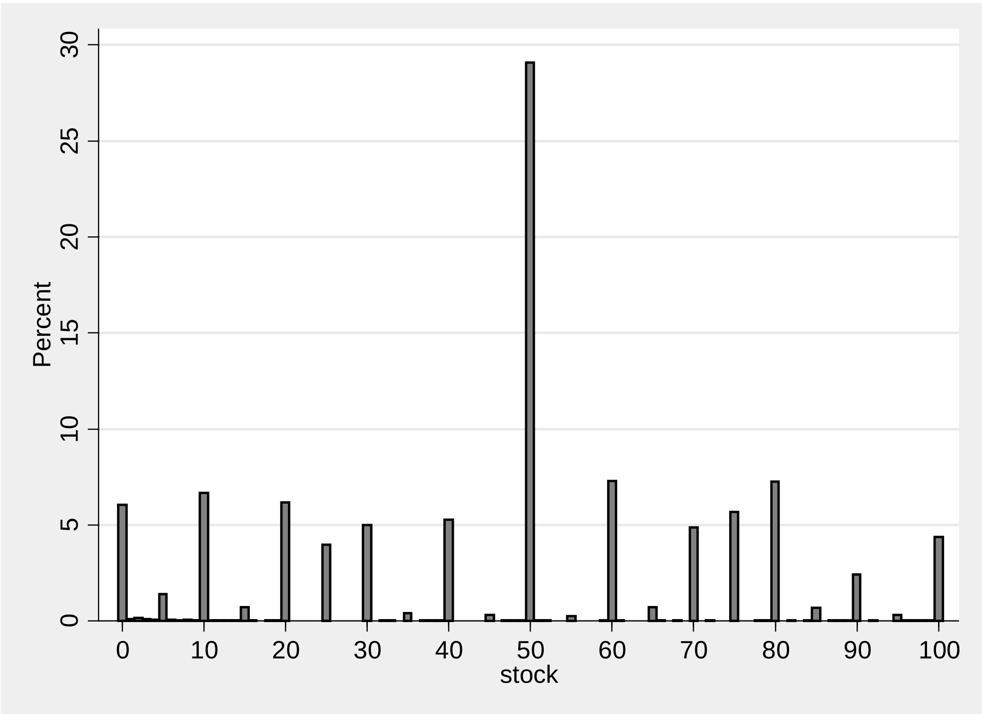

Figure A2 Distribution of Numerical Responses: Stock Market

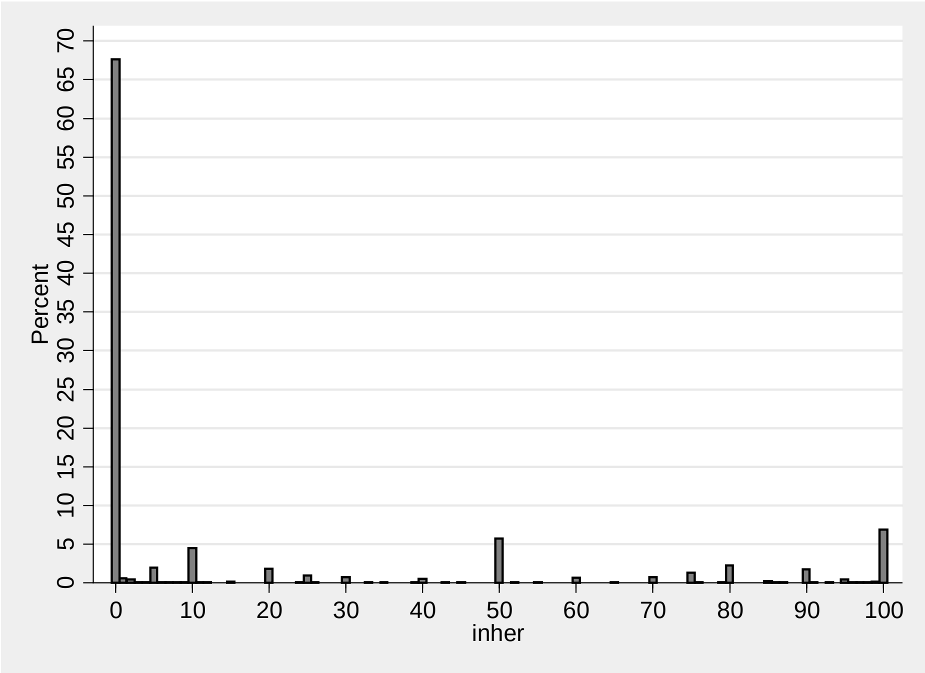

Figure A3 Distribution of Numerical Responses: Inheritances

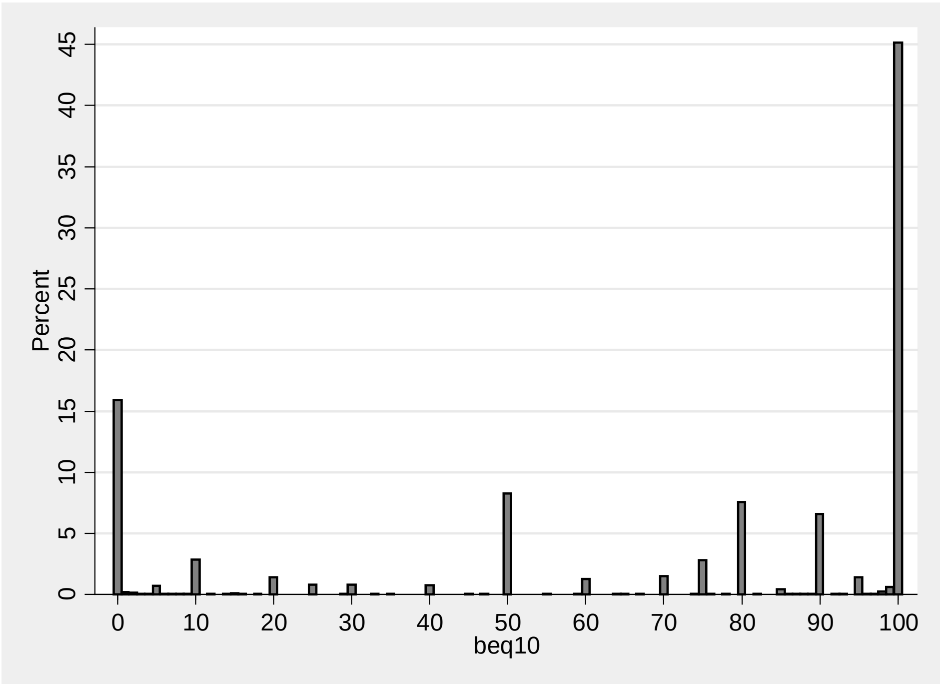

Figure A4 Distribution of Numerical Responses: Bequests

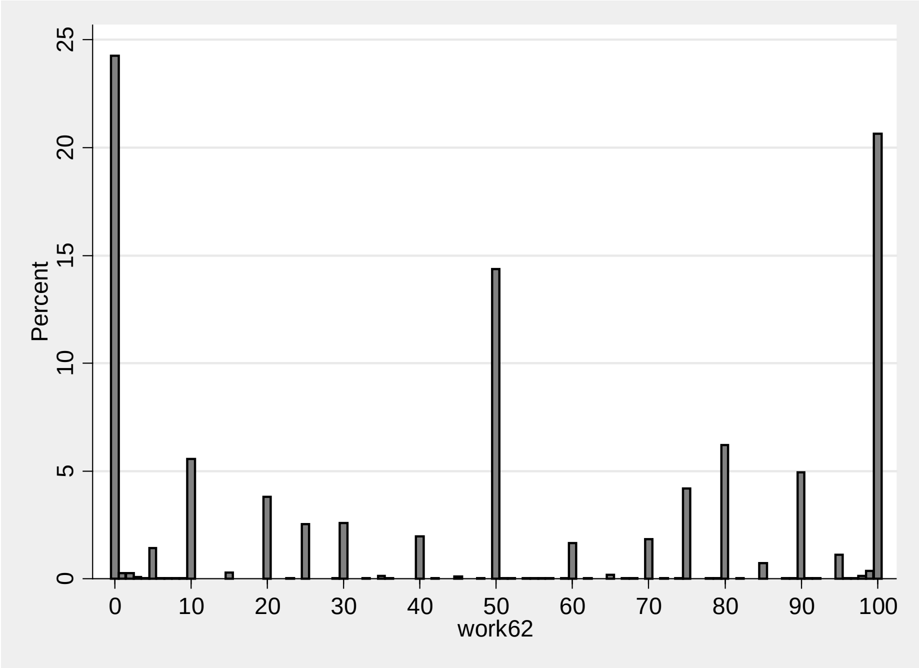

Figure A5 Distribution of Numerical Responses: Work 62

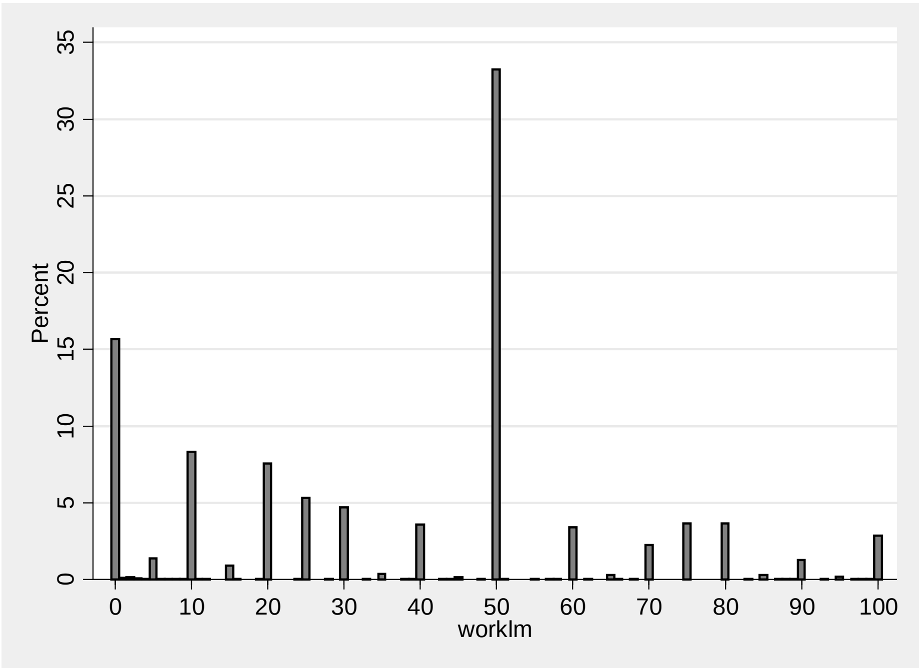

Figure A6 Distribution of Numerical Responses: Work Limitations