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Abstract

In a life-cycle model with a bequest motive, we study the impact of smooth ambiguity aversion to uncertain survival probabilities on the optimal demand for annuities. We implement a theory-driven laboratory experiment. First, a subject's ambiguity attitude is elicited in a simple experimental setting able to make the smooth ambiguity model operational. Then, in a two-period annuity-bequest decision problem, the subject's bequest in the second period is presented as a donation to a previously chosen charity, contingent to the subject being active after the first period. In line with the theoretical predictions, we find that ambiguity-averse (resp., loving) subjects invest less (resp., more) in annuities than ambiguity-neutral ones. Furthermore, subjects' contingent donation to the chosen charity increases in their investment in annuities only for sufficiently high levels of warm-glow altruism.

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1 Introduction

This paper contributes to the understanding of the determinants of a specific form of self-insurance—investment in annuities—through a theory-driven laboratory experiment.

Annuities are financial securities that help to deal with lifetime uncertainty and the linked variation in savings. They are designed to be a reliable means of securing a steady cash flow for individuals during their retirement years and to alleviate fears of longevity risk, or outliving one's assets. More precisely, an **annuity** is a contract between an individual and an insurance company. The individual puts money in, essentially investing through the insurance company. In exchange, the insurance company gives him the opportunity to annuitize that money, *i.e.*, to receive guaranteed income payments for the rest of his/her life. The annuity provides constant returns—largely above those of bonds—if the bearer is alive, and no return otherwise. Therefore, this financial product should be particularly attractive for retirees who find themselves increasingly exposed to **longevity risk**, *i.e.*, to the risk of being unable to sustain their consumption should they live longer than average.

According to the life-cycle model of consumption with uncertain lifetime proposed by Yaari (1965), agents who do not care for bequests should invest all their wealth in annuities. Thus, full annuitization should be the optimal strategy followed by a rational individual without altruistic motives (concerns for his/her spouse and children). Davidoff *et al.* (2005) have revisited Yaari's (1965) results in a simpler discrete-time setting and under a somewhat more general asset structure. They show that positive annuitization still remains optimal under very general specifications and assumptions, including intergenerational altruism and market frictions.

However, these theoretical predictions do not meet the facts. The predicted investment of wealth at retirement in actuarially fair annuities of typical 65-year-old individuals is by far higher than the actual demand for annuities, thereby leading to the so-called **under-annuitization puzzle**. In fact, despite the retirement income benefits that it provides, annuitization has been and remains a relatively unpopular option. At the beginning of this century, the private annuity markets in Australia, Canada, Chile, Israel, Singapore, Switzerland, the UK and the US, were under-developed, especially relative to the life insurance market (see James & Song 2001).[1] The situation has not changed much in recent years, with elderly population showing a low willingness to invest in annuities even in countries where this product is easily accessible.[2]

[1] Johnson *et al.* (2004) documented that in US defined-contribution savings plans, only 10% of participants who left their job after age 65 in 1992-2002 annuitized their assets. They estimated that in the same period, among people at least 65 years old in the US, private annuities comprised just 1% of total wealth. Inkmann *et al.* (2011) analyzed data from the English Longitudinal Study of Ageing, a biannual panel survey among those aged 50 and over living in private households in England in 2002. They showed that only 6% of the households in their sample received income from voluntary annuitization.

[2] Benartzi *et al.* (2011) analyzed more than 103,000 payout decisions from 112 different US defined-benefit pension plans during 2002-2008. About half of elder participants took their entire retirement benefit as a lump sum, even though the annuity was the default option and opting out required time-consuming paperwork (see also Previtero 2014). In the UK, until 2014 the rules forced people to buy an annuity when they retired. Since March 2015, about 4.2 million British savers over the age of 55 have more freedom to manage their retirement pots. Customer research conducted shortly after the announcement indicated that only one in three people aged 50 to 75 intended to buy a traditional annuity, and then only for a

Several theoretical extensions have been provided so as to account for the under-annuitization puzzle (see Brown *et al.*, 2013, for a review). Although the literature to date has failed to identify a sufficiently general explanation for consumers' aversion to annuities, it has nonetheless highlighted three factors that should be incorporated in life-cycle models so as to mitigate the puzzle.

First, the *bequest motive*. Lockwood (2012) extends Davidoff *et al.* (2005) in order to also account for actuarially unfair annuities. He finds that a combination of realistic pricing loads and moderate bequest motives can render annuities unattractive in an optimizing model. His findings are consistent with Yogo (2016), who needs a bequest motive to generate low welfare gains from annuity market participation in a model with health investments.

Second, an *investment frame*. Brown *et al.* (2008) propose that instead of evaluating annuities within a consumption frame (focusing on the end result of what the bearer can spend over time), one should adopt an investment frame (focusing on the intermediate results of return and risk features when choosing assets). They provide survey evidence that in an investment frame, individuals find annuities quite unattractive, exhibiting high risk without high returns, and thus prefer non-annuitized products. In line with their results, Hu & Scott (2007) show how loss aversion (and other behavioral distortions) can make annuities look undesirable: annuities are viewed as risky gambles where potential losses loom larger than potential gains should the bearer die earlier than expected.

Third, *uncertain survival probabilities*. d'Albis & Thibault (2012, 2018) extends the Yaari's (1965) framework by assuming that the individual does not know his/her survival probability. They show that for an individual with maxmin expected utility *à la* Gilboa & Schmeidler (1989) or with smooth ambiguity preferences *à la* Klibanoff *et al.* (2005, henceforth KMM) it is optimal not to annuitize but to purchase pure life insurance policies instead. Reichling & Smetters (2015) reach a similar conclusion through a different extension of Yaari (1965): they allow a household's mortality risk to be stochastic due to health shocks. In this framework, lifetime annuity still helps to hedge longevity risk, but the annuity's remaining present value is correlated with medical costs. They predict that most households should not hold annuities, and many should hold negative amounts.

In this paper we consider together these three factors potentially explaining the under-annuitization puzzle. We propose an experimental study of a two-period life-cycle model with consumption and bequest similar to Davidoff *et al.* (2005), and we assume, as in Yaari (1965), no market imperfections and some warm-glow altruism. At period 1, an individual decides how to share his income between bonds and actuarially-fair annuities in an *investment frame*.[3] He/she derives utility from a bequest that might happen at the end of period 1 or period 2 and, upon survival, from consumption in period 2. As discussed above, a *bequest motive* is necessary to obtain some partial annuitization but it does not eliminate the advantage of annuities since they return more, in case of survival,

portion of their assets. Koch *et al.* (2015) estimate that annuities' share of in-retirement products could decline from the current 75% to about 30% to 40%.

[3] d'Albis & Thibault (2012) have analyzed the same problem in a maxmin model, *i.e.*, with an infinite degree of KMM-ambiguity aversion, and shown that from a qualitative point of view the decision problem is the same with or without consumption allowed in period 1. Therefore, we claim that our stylized setup without consumption allowed in period 1 is sufficient to study under-annuitization.

than regular bonds. As an additional factor of under-annuitization, we assume ambiguity aversion toward *uncertain survival probabilities*, and we model this aversion with smooth ambiguity preferences *à la* KMM, as in d'Albis & Thibault (2018).

The assumption of **Knightian uncertainty (*i.e.*, ambiguity) on survival probabilities** receives strong empirical support. It is natural that demand for annuities increases with life expectancy (see, *e.g.*, empirical results in Inkmann *et al.* 2011). However, despite all the available information displayed in Life Tables, survival probabilities are nevertheless ambiguous to individuals, due to at least three reasons: (*i*) a rather strong individual heterogeneity in the age at death (see, *e.g.*, the empirical analyses in Edwards & Tuljapurkar 2005, Bell & Miller 2005, and Benartzi *et al.* 2011); (*ii*) changes in the distribution of survival probabilities at each age in the last century due to opposite factors such as medical progress versus the emergence of new epidemic diseases (see, *e.g.*, Cutler & Meara 2004); (*iii*) unreliable data about last years of life, due to small number of observations and absence of a consensus among demographers about the mean survival rate (see, in particular, Oeppen & Vaupel 2002).

The assumption of an **aversion toward the ambiguity of survival probabilities** is also supported by a great deal of evidence. This does not only concern health issues (see, *e.g.*, Viscusi *et al.* 1991 about individuals' aversion to ambiguous information on the risk of lymphatic cancer). It is also detected in real case studies on environmental risks (see Riddel & Shaw 2006 on the unwillingness to be exposed to the "unknown" risks associated with nuclear waste transportation). Furthermore, and more importantly for our study, aversion to ambiguous survival probabilities has been somehow detected in portfolio and life-cycle decisions: Post & Hanewald (2013) have shown that individuals are aware of longevity risk and that this awareness affects their savings decisions.

With all this in mind, the contribution of our study to the current debate on the self-insurance role of investing in annuities is twofold. In a theory-driven laboratory experiment, we elicit ambiguity aversion and we show that—if interpreted as aversion to ambiguous survival probabilities—it is a good candidate to explain the empirically observed under-annuitization puzzle. Furthermore, we analyze the interplay between this specific form of self-insurance and voluntary bequests (upon survival), through a novel experimental design where the "next generation" is a real charity receiving the subject's voluntary bequests soon after the end of the experiment. To the best of our knowledge, ours is the first study measuring ambiguity attitude in a traditional experimental task and using this measurement to explain low demand for annuities in a life-cycle model with a bequest motive.

Subjects' degree of ambiguity aversion is elicited in **phase A of the experiment** through a simple mechanism able to make KMM's smooth ambiguity model operational. Recall that, as in d'Albis & Thibault (2018), aversion to ambiguous survival probabilities is introduced into the Yaari's (2005) annuity-bequest framework through a non-expected utility model (KMM). Several experimental studies (*e.g.*, Halevy 2007, Chakravarty & Roy 2009, Conte & Hey 2013, Ahn *et al.* 2014, Baillon & Bleichrodt 2015, Cubitt *et. al* 2018, 2019) find support for KMM in choice under uncertainty. Here we rely on a simplified version of a mechanism in Attanasi *et al.* (2014), designed ad hoc to experimentally identify KMM-coherent subjects. It consists in a combined elicitation of two features of a subject's ambiguity attitude, namely the value-ambiguity attitude and the choice-ambiguity attitude. This provides a robust test of the sign of the ambiguity attitude that a subject discloses in the experiment. Subjects showing at the same time value-ambiguity aversion (resp., proneness) and choice-ambiguity proneness (resp., aversion) in phase A are not considered in the analysis of behavior in phase B. This is because their behavior in phase A is incoherent with the predictions of KMM, our reference model in phase B.

In **phase B of the experiment**, we let subjects participate in the two-period annuity-bequest decision problem discussed above (life-cycle framework). In the first period, the choice between annuities and bonds is proposed to subjects in an investment frame ("investing" means choosing annuities, "not investing" means choosing bonds). As discussed above, in line with Brown *et al.* (2008), with such framing annuities should be unattractive to an ambiguity-neutral subject with low warm-glow altruism. The novelty of our approach is in the way we measure warm-glow altruism and in the mechanism we use to implement subjects' bequests to a next generation in the lab.

Bequests are presented as donations to a charity. Indeed, at the end of phase A, each subject is asked to indicate—through Web search—a charity to which he/she would like to donate part of the earnings he/she would eventually get in phase B. A short charity-related questionnaire follows. Our auxiliary assumption is that answers to this questionnaire provide a measure of the subject's utility from the act of giving to the charity in phase B. Donations to the charities are implemented by the experimenter within 24 hours by the end of the experiment, with each subject getting private E-mail confirmation of his/her own donation.

This feature of the design has two main advantages. On the one side, it allows us to create a tie between the donor and the bequest's receiver, which it would not be the case if the latter were a randomly matched subject in the lab. On the other side, it avoids undesired effects of post-experiment bequest sharing and unreliable measures of warm-glow altruism if the receiver were a relative or a friend of the experimental participant.

After Andreoni's (1989) model of warm-glow altruism, several experimental studies have confirmed that warm glow is an important factor in monetary donations to a charity (for a review, see Brown *et al.* 2013). In particular, Crumpler & Grossman (2008) show that agents give some of their own money to charity even when their donation does not alter the total amount donated to the charity. That is, individuals are giving for pure warm-glow reasons, not to expand the amount available to the charity.

Some experiments have been run about how donors' behavior extends to environments with uncertain income. This literature is relevant for our experiment, since in phase B of our design subjects choose the amount of the bequest in period 2 through the strategy method, *i.e.*, before the uncertainty about "survival" and the income in period 2 is resolved. In this regard, Kellner *et al.* (2015) have proved that it is cheaper to commit to donate to a charity before the uncertainty is resolved, and so a larger donation is required to maintain a positive image. This result is in line with Converse *et al.* (2012), who find that the combination of wanting an outcome and lack of control under uncertainty increases donations to charity, and suggest that this is due to a belief that one's donations increase the likelihood of the desirable outcome. For all these reasons, we should expect elicited bequests in phase B of our experiment to be larger than theoretically predicted. However, this effect is compensated by the fact that in our annuity-charity decision problem, charities receive a (involuntary) bequest also in the case of "no survival" in period

2, namely the amount invested in bonds in period 1. Thus, the above-mentioned behavioral distortions on the voluntary bequest in the favorable state of the world should be mitigated by the possibility of an involuntary bequest in the unfavorable one.

Our experimental results confirm the theoretical prediction of a negative impact of ambiguity aversion and a positive impact of ambiguity proneness on the demand for annuities. Indeed, in period 1, ambiguity-averse subjects invest significantly less in annuities than ambiguity-neutral ones, and ambiguity-loving subjects invest significantly more than the latter. Furthermore, warm-glow altruism and giving play no significant effect on the demand for annuities.

In period 2, as assumed in our theoretical framework, we find that the way the subject shares his/her financial wealth if active is independent from his/her ambiguity attitude. In line with the theory, we observe that the amount the subject decides to keep for him/herself is increasing in the annuities purchased in period 1. However, the subjects' bequest to the chosen charity is non-decreasing in the investment in annuities. We find it increasing only for those subjects donating to charities which they perceive as "closer" in terms of own participation and/or involvement, thereby experiencing a sufficiently high level of warm-glow altruism through their voluntary donation.

The rest of the paper is structured as follows. Section 2 presents our model of annuitization and bequest under ambiguous survival probabilities. Section 3 describes the experimental design, discusses our operational measure of ambiguity attitude, and presents our experimental hypotheses. Section 4 presents and discusses our experimental results in light of the theoretical predictions. Section 5 concludes by framing our contribution within the experimental literature of self-insurance decisions. An Online Appendix collects technical details about the theoretical analysis (Online Appendix A), the experimental instructions (Online Appendix B), and the data analysis (Online Appendix C).

2 A model of annuitization with ambiguity and bequest

This section applies the recent rationale for ambiguity proposed by KMM to a static model of consumption and bequest under uncertain lifetime similar to Yaari (1965) and Davidoff *et al.* (2005).

The length of life is at most two periods with the second one being uncertain. The Decision Maker (DM, hereafter) derives utility from a bequest that might happen at the end of periods 1 and 2 and, upon survival, from consumption in period 2. At the first period, the DM is endowed with an initial positive income w that can be shared between bonds and annuities. Bonds return $R > 0$ units of consumption in period 2, whether the DM is alive or not, in exchange for each unit of the initial endowment. Conversely, annuities return $R_a \geq R$ in period 2 if the DM is alive and nothing if she is not alive. Due to the possibility of dying, the demand for bonds should be non-negative. If alive during the second period, the DM may allocate her financial wealth between consumption and bequest. Since death is certain at the end of period 2, the latter is exclusively a demand for bonds.

We denote by a, the demand for annuities and by $w-a$, the demand for bonds, decided in period 1. Moreover, let c and x denote respectively the consumption and the bequest decided in period 2. The budget constraint in period 2 if the DM is alive writes:

$$c = R_a a + R(w - a) - x, \tag{1}$$

and the non negativity constraints are:

$$c \geq 0, \; x \geq 0, \; a \leq w. \tag{2}$$

Following Davidoff *et al.* (2005), we assume that whatever the length of the DM's life, bequests are received in period 3, involving additional interest: the bequest is therefore xR, if the DM is alive in period 2, while it is $(w - a)R^2$, if she is not.

As in Yaari (1965) and Davidoff *et al.* (2005), we assume that the DM's **state-dependent utility** is separable: $g[c] + h[xR]$ if alive in period 2 and $h[(w - a)R^2]$ if she is not alive.[4]

Importantly, we assume that **survival probabilities are uncertain**. More precisely, the DM does not know her own probability distribution but only knows the set of possible distributions. There exist states of nature associated with given survival probabilities that may be interpreted as health types, to which the DM subjectively associates a probability to be in. Ambiguity is hence modeled as a second-order probability over first-order probability distributions. Let us denote the random (continuous or discrete) survival probability by $\widetilde{p}$ whose support is denoted $\text{Supp}(\widetilde{p})$, and the survival expectancy as it is evaluated by the DM by $E(\widetilde{p}) = p$. More precisely, given that it does not affect the main results, we suppose that the principle of insufficient reason applies, and so p corresponds to the mean survival probability $E(\widetilde{p})$.

We also assume that the DM has **smooth ambiguity preferences**. Following KMM, ambiguity attitude is introduced using a function ϕ, a von Neumann-Morgenstern index function accounting for the attitude toward mean preserving spreads in the induced distribution of the lifetime expected (state-dependent) utility conditional to the unknown survival probability $\widetilde{p}$. Therefore, the DM's ex-ante utility is given by an expectation of an expectation (see KMM, p. 1851, Eq. (1)). The inner expectations evaluate the expected utilities corresponding to possible first-order probabilities while the outer expectation aggregates a transform of these expected utilities with respect to the second-order prior. The function ϕ determines ambiguity attitude of the DM in the sense that a concave (resp: convex) ϕ implies an ambiguity-averse (resp: ambiguity-loving) DM.

To implement a theory-driven laboratory experiment, we parametrize the annuity-bequest two-period decision problem as follows: $p = 1/2$, $w = 10$, $R = 1$, and $R_a = 2$. With this **parametrization**, $R_a = R/p$, *i.e.*, the annuities available for purchase are actuarially fair, as it is assumed in Yaari (1965). Furthermore, since $R = 1$, purchase of bonds is equivalent to transferring wealth across periods.[5] The two-stage uncertainty in the KMM framework is implemented with discrete first-order survival probabilities with $\text{Supp}(\widetilde{p}) = \{0, 1/10, 2/10, ..., 1\}$, and discrete second-order probabilities over $\text{Supp}(\widetilde{p})$.

[4] The twice continuously differentiable functions g and h are supposed to be positive, increasing and strictly concave. They also satisfy $g[0] = h[0] = 0$, and $\lim\limits_{\varrho \to 0} g'[\varrho] = \lim\limits_{\varrho \to 0} h'[\varrho] = +\infty$.

[5] In Sections 3.2.2 and 3.2.3, we will explain how the latter feature greatly simplifies the computational burden for experimental participants.

More precisely, call $p_\theta = \theta/10$ the unknown first-order probability, with $\theta \in \{0, 1, ..., 10\}$. Call q_θ the corresponding second-order probability.

With this, the lifetime expected utility of the second-stage lottery in period 1, denoted $\mathcal{U}(a, x, p_\theta)$, is the realization of the random variable $\mathcal{U}(a, x, \widetilde{p})$ in the state of the world θ that, for $\theta \in \{0, 1, ..., 10\}$, writes:

$$\mathcal{U}(a, x, p_\theta) = p_\theta\Big(g[10 + a - x] + h[x]\Big) + (1 - p_\theta)h[10 - a], \tag{3}$$

and the ex-ante utility function writes

$$\phi^{-1}(\sum_{\theta=0}^{10} q_\theta(\phi(\mathcal{U}(a, x, p_\theta)))), \tag{4}$$

where the twice continuously differentiable function ϕ is assumed to be increasing.

The DM faces the following annuity-bequest decision problem, denoted $\mathcal{P}_\phi$:

$$\max_{a,x} \;\; \phi^{-1}(\sum_{\theta=0}^{10} q_\theta(\phi(\mathcal{U}(a, x, p_\theta)))) \tag{5}$$
$$s.t. \;\; 10 + a - x \geq 0, \;\; x \geq 0 \text{ and } a \leq 10.$$

Then, upon existence, the solution $(a^\star_\phi, x^\star_\phi)$ of $\mathcal{P}_\phi$ satisfies the FOCs:

$$\sum_{\theta=0}^{10} q_\theta\Big(\phi'(\mathcal{U}(a^\star_\phi, x^\star_\phi, p_\theta))\Big[p_\theta\Big(g'[10 + a^\star_\phi - x^\star_\phi] + h'[x^\star_\phi]\Big) - (1 - p_\theta)h'[10 - a^\star_\phi]\Big]\Big) = 0, \tag{6}$$

$$-g'[10 + a^\star_\phi - x^\star_\phi] + h'[x^\star_\phi] = 0. \tag{7}$$

We remark that the survival probability p_θ affects the optimal demand for annuities but not, as shown by equation (7), the optimal allocation of the financial wealth between consumption and bequest. Furthermore, condition (7) can be used to define the application $x^\star_\phi = f(a^\star_\phi)$, which satisfies $0 \leq f'(a^\star_\phi) \leq 1$. Hence, at the optimum, if the DM survives, her bequest $f(a^\star_\phi)$ and her consumption $10 + a^\star_\phi - f(a^\star_\phi)$ increase with the demand for annuities $a^\star_\phi$. All this is formally stated in Proposition 1 (see Online Appendix A for the formal Proof).

Proposition 1. **(i)** Upon survival, the optimal share between bequest $x^\star_\phi$ and consumption $c^\star_\phi = 10 + a^\star_\phi - x^\star_\phi$ does not depend on the ambiguity attitude of the DM. **(ii)** Upon survival, (voluntary) bequests $x^\star_\phi$ and consumption $c^\star_\phi$ increase with the optimal demand for annuities $a^\star_\phi$.

If the trade-off between consumption and bequest if alive—*i.e.*, the DM's warm glow—is not affected by the ambiguity attitude of the DM, it is clear, from equation (6), that the ambiguity attitude plays a crucial role to determine the demand for annuities. We can establish that:

Proposition 2. The optimal demand for annuities $a_\phi^\star$ which solves the problem $\mathcal{P}_\phi$: **(i)** is positive and denoted $a_0^\star$ if the DM is ambiguity-neutral; **(ii)** is lower than $a_0^\star$ if the DM is ambiguity-averse; **(iii)** is larger than $a_0^\star$ if the DM is ambiguity-loving.

Here we provide a qualitative explanation of Proposition 2 based on intuition (see Online Appendix A for the formal Proof). Ambiguity attitude determines the optimal exposure to uncertainty. An ambiguity-averse DM chooses to be less exposed that an ambiguity-neutral DM, which means that she aims at smoothing the expected utilities computed in each state of nature. This can be achieved by reducing the share of annuities in the portfolio.

Let us point out that this result may not be so "trivial", as one may erroneously think an annuity as an insurance product whose demand should increase with the aversion to uncertain lifetime. Let us now explain why this is not the case by considering only two states of nature, *e.g.*, $\theta \in \{1, 9\}$, for which the survival probabilities are respectively $p_1 = 1/10$ and $p_9 = 9/10$. Using equation (3), the optimal difference of expected utilities in both states is thus:

$$(p_9 - p_1)\Big(g[10 + a_\phi^\star - x_\phi^\star] + h[x_\phi^\star] - h[10 - a_\phi^\star]\Big), \tag{8}$$

which is proportional to the optimal difference between the utility if the DM lives for two periods and the utility if she lives for one period only. As the utility depends on the bequest, the sign of the latter difference is not a priori given. However, it can be proven that the latter difference is always positive, and that reducing the demand for annuities reduces difference (8). The intuition is that, upon survival, the utility increases with the share of annuities in the portfolio. As a consequence, to reduce the exposure to life uncertainty, an ambiguity-averse DM has to increase her demand for bonds, and reduce her demand for annuities. Conversely, an ambiguity-loving DM would prefer to increase the exposure to life uncertainty, by increasing the difference (8) and, consequently, by reducing her demand for bonds and increasing her demand for annuities.[6]

3 An experimental test with charitable giving

3.1 The experimental protocol

Participants were 100 students of University of Strasbourg (60 male, 40 female; 67 undergraduate, 33 graduate; 70 in Economics, 7 in other Social Sciences, 9 in Human Sciences, and 14 in Natural Sciences). The experiment was run at the Laboratory of Experimental Economics of Strasbourg (LEES). Students were recruited through ORSEE (Greiner 2015). Four sessions of 25 subjects each were conducted at the LEES. Each person could only participate in one of these sessions. The experiment was programmed and implemented using the platform www.econplay.org of the LEES.

[6]The limit case such that the ambiguity aversion is infinite, was studied by d'Albis & Thibault (2012, 2018). It reveals that there exists a threshold above which the demand for annuity is nil when negative annuitization is not allowed.

Average earnings were €22.57, including an average transfer of €4.00 to a charity chosen by each participant during the experiment, as it will be explained below. The average duration of a session was 70 minutes, including instructions and payment.[7]

3.2 The experimental design

The experimental design is made of two phases (A and B), always implemented in the same order. Instructions of phase B are given and read aloud only prior to that phase.

Table 1 offers a schematic representation of the experimental design, summarizing its main features and how the 100 subjects are funneled through the two orders of presentation of tasks of phase A. In particular, among the four sessions with 25 participants each, two sessions are implemented with the main treatment 1-2-3-4 (the order of tasks shown in Table 1), and other two with the order treatment 4-3-2-1. Subjects voluntarily enrolling for the experiment are randomly allocated to one of the four sessions, hence half of them to a 1-2-3-4 session, and the other half to a 4-3-2-1 session.

Phase A	**Task 1**: Elicitation of *value* of a lottery with *known* probabilities	- 50 subjects: order 1-2-3-4 - 50 subjects: order 4-3-2-1
	Task 2: Elicitation of *value* of a lottery with *unknown* probabilities	
	Task 3: Elicitation of *choice* among lotteries with *known* probabilities	
	Task 4: Elicitation of *choice* among lotteries with *unknown* probabilities	
Phase B	**Indication of a charity** to which eventually donate part of earnings in phase B	Same order for all 100 subjects
	Charity-related questionnaire	
	Instructions of the two-period investment-donation decision problem distributed	
	Control questions about the two-period investment-donation decision problem	
	Two-period investment-donation decision problem: - **Period 1**: *investment* (choice among lotteries with *unknown* probabilities) - **Period 2**: *donation* (to the chosen charity) if *active* in period 2 (*strategy method*)	
Final questionnaire	Elicitation of gender, age, year and field of study, and self-assessed time discounting	
Payment	*Subject* (sum of *earnings* in phase A and phase B): - Phase A: one of the four tasks randomly selected and paid - Phase B: if active in period 2, investment choice paid net of donation choice	
	Charity: *donation* implemented within 24 hours, confirmation sent to the subject	

Table 1. Experimental design: main features

Phase A is meant to elicit a subject's ambiguity attitude within the smooth ambiguity model of KMM, in a battery of portfolio choice problems with ambiguous returns. This portfolio choice elicitation method is obtained as a combination of two well-known experimental designs: Halevy (2007) elicitation of lottery certainty equivalents (tasks 1 and 2), and Eckel & Grossman (2002) ordered lottery selection (tasks 3 and 4). Ambiguity characterizes tasks 2 and 4 of phase A. Following Attanasi *et al.* (2014), behavior in tasks 1 *vs.* 2 discloses *value*-ambiguity attitude, and behavior in tasks 3 *vs.* 4 discloses *choice*-ambiguity attitude. Coherence (equivalence) between the two attitudes is a necessary condition implied by the smooth ambiguity model of KMM.

[7]The English translation of the instructions is provided in Online Appendix B.

Phase B is meant to elicit subjects' investment in annuities in a life-cycle framework *à la* Davidoff *et al.* (2005), where the annuity *vs.* bond decision is taken in period 1, and a bequest (donation to a *charity*) is chosen in period 2 and implemented in period 3 (*i.e.*, after the end of the experiment). This two-period investment-donation decision problem is the experimental implementation of the static decision problem of consumption and bequest under uncertain lifetime theoretically analyzed in Section 2. In particular, the investment problem of period 1 is an extension of Gneezy & Potters (1997) betting game to a situation where the subject is also uncertain about whether he/she can manage the money earned in period 1. Ambiguity characterizes period 1: the probability that the subject will be active in period 2 is *unknown.*

A **final questionnaire** about some idiosyncratic features is submitted at the end of the experiment. Each subject is asked his/her gender, age, year and field of study, and a question about self-assessment of time discounting.[8]

As for the experimental **payment**, at the end of the experiment, after the subject's earnings and charity donation in phase B are determined, one of the four tasks of phase A is randomly selected and performed, thereby determining subject's earnings from phase A. Then, the sum of *subject's earnings* from phase A and from phase B is individually paid in cash. The subject's *donation to the charity* in phase B, if any, is implemented by the experimenter immediately after the end of the experiment, and the donation receipt sent to him/her within 24 hours after the end of the experiment.

In the next two subsections, we present the specific design features of phase A and phase B, separately. In the last subsection, we discuss more in depth some key features of our design.

3.2.1 Phase A

Phase A is made of tasks 1-4, presented in reverse order in half of the sessions (50 subjects for each order). At the end of the experiment, only one of the four tasks is randomly selected and actually performed, so as to determine earnings of phase A.[9] Instructions of a new task are given and read aloud only prior to that task.

Task 1 is a choice between a lottery with *known* probabilities and a battery of ten fixed amounts of money, presented on ten consecutive lines (see Screen 1 in Online Appendix B). More precisely, each subject is given two options, Left and Right. Option Left is a lottery L^1 with two outcomes, €0 and €20, and 50% probability each—10-ball urn with 5 yellow balls and 5 blue balls—*i.e.*, $L^1 = (20, 0.5; 0, 0.5)$.[10] Option Right gives instead

[8] This is a standard one-year matching question (see, *e.g.*, Thaler 1981) under a "delay premium" framing *à la* Loewenstein (1988): "You have the possibility to receive immediately €100 for your leisure. How much money do you need in order to give up on spending the €100 today and carry them over to the next year?", the set of possible answers being integer numbers from 0 to 100. Thus, the higher the selected number, the lower the willingness to accept a delayed payment, and so the higher the intertemporal discount rate.

[9] More precisely, at the end of the experiment one of the subjects is asked to make a random draw from an envelope containing four numbers. The drawn number (1, 2, 3, or 4) indicates the number of the task that is performed for all subjects in the session: the computer randomly selects a ball from the urn associated to this task. The color of the randomly selected ball is used to determine all subjects' earnings.

[10] Before the experiment starts, each subject is asked to choose one of two colors: yellow or blue. The chosen color is the one that will be associated to the highest of the two outcomes for each lottery that

a sure amount €X_i, with X_i being an odd number with min $X_1 = 1$, max $X_{10} = 19$, and $X_i = X_{i+1} - 2$ for each $i = 1, ..., 9$. For each of the ten X_i, the subject is asked to indicate whether he/she prefers Left or Right. In particular, monotonicity is exogenously imposed: the subject is asked to choose the lowest X_i for which he/she prefers option Right to option Left.[11] Call this *value* X^1, where the superscript indicates task $t = 1$.

Subject's earnings: If task 1 is the randomly selected task at the end of the experiment, the computer randomly draws one of the ten amounts $X_i \in \{1, 3, ..., 19\}$ (same for all subjects, with each X_i having the same probability to be drawn). If, for this randomly drawn amount $\tilde{X}_i^1$, the subject has indicated that he/she prefers option Left, *i.e.*, $\tilde{X}_i^1 < X^1$, then lottery L^1 is played: one of the ten balls is randomly drawn by the computer, and his/her earnings are €20 (€0) if the ball is yellow (blue). If for $\tilde{X}_i^1$ the subjects has indicated instead that he/she prefers option Right, *i.e.*, $\tilde{X}_i^1 \geq X^1$, his/her earnings are $\tilde{X}_i^1$, *i.e.*, the randomly drawn amount.

Task 2 is the same as task 1, apart from the fact that here option Left is a lottery L^2 (the superscript indicating task $t = 2$) with the same two outcomes as L^1 but *unknown* probabilities, *i.e.*, $L^2 = (20, \widetilde{p}; 0, 1 - \widetilde{p})$. More precisely, the 10-ball urn used for task 2 has an unknown composition of yellow and blue balls: $\widetilde{p}$ can take one of the eleven values in $\{0, 0.1, ..., 0.9, 1\}$ (see Screen 2 in Online Appendix B, with option Left indicating an urn with 10 grey balls rather than the 5-5 yellow-blue balls urn of Screen 1). In fact, the composition of the ambiguous urn is the same for all subjects in a session. They are told that it was determined prior to the experiment by randomly drawing one of the eleven possible compositions of yellow-blue balls (0-10, 1-9, ..., 9-1, 10-0). Each composition had the same probability to be drawn, although subjects were not told about this. Call *value* X^2 the lowest X_i for which the subject prefers option Right to option Left in task $t = 2$.

Subject's earnings: If task 2 is the randomly selected task at the end of the experiment, $\tilde{X}_i^2$ is randomly drawn following the same procedure as for $\tilde{X}_i^1$ for task 1, and the comparison between $\tilde{X}_i^2$ and X^2 determines the subject's earnings. However, if $\tilde{X}_i^2 < X^2$, and so lottery L^2 is played, the random draw of a ball is made by the computer from the urn with unknown composition described above.

Task 3 is a choice among ten two-outcome lotteries $L_1^3, L_2^3, ..., L_{10}^3$ (the superscript indicating task $t = 3$), with same *known* probabilities and same mean, presented on ten consecutive lines (see Screen 3 in Online Appendix B). As for task 1, a 10-ball urn with 5 yellow and 5 blue balls is used, so all lotteries are of type $L_j^3 = (\overline{x}_j, 0.5; \underline{x}_j, 0.5)$, with $\overline{x}_j = 10 + j$ and $\underline{x}_j = 10 - j$, for $j = 1, 2, .., 10$. By construction, all lotteries have mean 10, and standard deviation increasing in j, hence lowest for $j = 1$, *i.e.*, for $L_1^3 = (11, 0.5; 9, 0.5)$, and highest for $j = 10$, *i.e.*, for $L_{10}^3 = (20, 0.5; 0, 0.5)$. The latter coincides with L^1 of task 1. Call *choice* j_3^* the chosen line and $L_{j^*}^3$ the chosen lottery in task 3.

Subject's earnings: If task 3 is the randomly selected task at the end of the experiment, the computer randomly draws one of the ten balls of the urn with known composition (5 yellow balls, 5 blue balls). The subject's chosen line j_3^* in task 3 determines the played

the subject would play in the experiment with an urn with yellow and blue balls. From now on, the experimental design is explained under the assumption that the color chosen by the subject before the experiment starts is *yellow.* This is without loss of generality: the same rules of the decision problem also hold if assuming that the chosen color is blue, and inverting "yellow" with "blue" in what follows.

[11] For a comparable study where monotonicity is imposed in a similar task, see Attanasi *et al.* (2018).

lottery $L^3_{j^*}$: if the randomly drawn ball is yellow, the subject's earnings are $(10+j^*_3)$ euros; otherwise, his/her earnings are $(10-j^*_3)$ euros.

Task 4 is the same as task 3 (the ten lotteries L^4_j with $j=1,2,...10$ have the same two outcomes as L^3_j for each j). However, outcome probabilities are *unknown*, *i.e.*, $L^4_j = (\overline{x}_j, \widetilde{p}; \underline{x}_j, 1-\widetilde{p})$. As for task 2, the 10-ball urn used for task 4 has an unknown composition of yellow and blue balls: $\widetilde{p}$ can take one of the eleven values in $\{0, 0.1, ..., 0.9, 1\}$ (see Screen 4 in Online Appendix B, where an urn with 10 grey balls is shown, rather than the 5-5 yellow-blue balls urn of Screen 3). The composition of the ambiguous urn is the same for all subjects in a session. They are told that it was determined prior to the experiment by randomly drawing one of the eleven possible compositions of yellow-blue balls. Each composition had the same probability to be drawn (subjects were not told about this). The composition of the two urns of tasks 2 and 4 has been determined through two independent random draws. Call *choice* j^*_4 the chosen line and $L^4_{j^*}$ the chosen lottery in task 4.

Subject's earnings: If task 4 is the randomly selected task at the end of the experiment, differently from task 3, the random draw of a ball by the computer is made from the urn with unknown composition described above.

At the end of phase A, none of the four tasks is actually performed. Subjects move directly to phase B.

3.2.2 Phase B

Phase B begins with the subject being asked to **indicate a charity** to which he/she would like to donate part of the earnings that he/she would get in the decision problem he/she will participate in phase B.[12] A short **charity-related questionnaire** follows. It is meant to elicit the relation of the subject with the chosen charity[13] and his/her perceptions of others' and own altruism.[14]

The subject faces the choice of the charity and the related questionnaire before instructions of the decision problem they will participate in phase B are distributed. They concern the following **two-period investment-donation decision**.

In **period 1** the subject is given 10 euros and he/she has to decide how many of them to invest, where $a \in \{0, 1, ..., 10\}$ is the *invested amount* and $10-a$ the *amount not invested.*

There are two possible outcomes in **period 2** for the invested amount in period 1. These two outcomes are determined through a 10-ball urn with *unknown* composition of yellow and blue balls. Thus, it may contain from 0 to 10 yellow balls and from 0 to 10 blue balls. The composition of the urn, which is the same for all subjects, has been determined

[12]The subject is given 5 minutes to find the website of the chosen charity and copy-paste it on the screen of the experimental software.

[13]The four questionnaire items are: "For how many years have you known this charity?"; "How many times have you already donated to this charity?"; "Did you ever participate in the activities of this charity?"; "Is any of your relatives or friends directly concerned by this charity?".

[14]The two questionnaire items are, respectively: "Would you say that most of the time people only care about themselves or they try to help others?"; "Would you say that most of the time you only care about yourself or you try to help others?". Possible answers to each question are on a scale from 0 (only care about oneself) to 10 (help others).

before the experiment by randomly drawing one of the eleven possible compositions of balls. Each composition had the same probability to be drawn, although subjects were not told about this. The composition of this ambiguous urn has been determined through a random draw independent from those made to compose the two ambiguous urns of task 2 and task 4 of phase A.

The random draw of a ball from the urn at the beginning of period 2 has two consequences. The first one concerns the *subject's earnings*: if the drawn ball is yellow, then in period 2 the invested amount is multiplied by 2 ($2a$); if the drawn ball is blue, then in period 2 the invested amount is lost (0). The second one determines whether or not the subject is *active* in period 2:

- if the drawn ball is yellow, then the subject is *active* in period 2: his/her total wealth at the beginning of period 2 is the sum of the amount not invested and two times the invested amount, *i.e.*, $(10 - a) + 2a = 10 + a$ euros. Then, in period 2 the subject chooses how much of this $(10 + a)$ euros he/she wants to *donate* to the previously chosen charity (x) and how much he/she wants to keep for him/herself $(10 + a - x)$. Hence, x is the *voluntary donation* to the charity, *i.e.*, conditional to the subject being *active* in period 2.

- if the drawn ball is blue, then the subject is *not active* in period 2 (there is no choice he/she can make): the only amount that is not lost, *i.e.*, the one not invested in period 1, $(10-a)$ euros, is directly donated to the previously chosen charity. This is the *involuntary donation* to the charity, *i.e.*, conditional to the subject *not* being *active* in period 2.

To summarize, if a yellow ball is randomly drawn at the beginning of period 2, the subject's earnings in phase B are $(10 + a - x)$ and the donation to the charity is x, with x being chosen by the (active) subject in period 2; otherwise, the subject earns nothing in phase B and the donation to the charity is $(10 - a)$, with this donation not being chosen by the (inactive) subject in period 2.

After the instructions of the two-period investment-donation decision problem have been read aloud by the experimenter, the subject is asked to go through two sets of four **control questions**, aimed at stating his/her comprehension of the decision problem. Each set of questions involves an example of (a, x) choice, and questions about the subject's earnings and the voluntary/involuntary donation to the charity for each color of the randomly-drawn ball.

Then, period 1 of the decision problem is performed: the subject chooses the invested amount a. At the end of period 1, the subject chooses x, according to a *strategy method*: he/she indicates the amount of the voluntary donation to the charity before knowing whether he/she will be actually active in period 2, *i.e.*, before the random draw of the ball from the ambiguous urn. Phase B ends with this random draw, same for all subjects, and the determination of *subject's earnings* from phase B and his/her donation to the charity.

The subject's voluntary or involuntary *donation to the charity*, if any, is implemented by the experimenter immediately after the end of the experiment, and the donation receipt sent to him/her within 24 hours after the end of the experiment. This last step of the design can be interpreted as period 3 of phase B,[15] where the experimental subject is no more active, independently from his/her choices and random events in periods 1 and 2.[16]

[15] Recall that in the model of Section 2 bequests are received in period 3.

[16] More precisely, before participating in the decision problem of phase B, the subject is told that (quoting

3.2.3 Comments on the experimental design

In this section we comment on some important features of the experimental design, and provide motivations for specific design choices.

Several **design features of phase A** deserve to be discussed:

(A.1) *Other relevant designs.* Besides the one of Halevy (2007) from which our phase A takes inspiration, other designs might be used to elicit ambiguity attitude within a KMM framework. We quickly present some of the most well known, in a chronological order.
Chakravarty & Roy (2009) use as experimental instrument a multiple price list method (comparable to our tasks 1-2), able to disentangle risk attitude and ambiguity attitude, and to capture differences in behavior under uncertainty over gains *vs.* losses.
Ahn *et al.* (2014) simulates a standard portfolio problem, more framed than our tasks 3-4: the subject has to allocate his/her wealth among three assets under a budget constraint. Each asset pays depending on the color of the ball drawn from an Ellsberg-like 3-color urn. The prices of assets are exogenously varied. Unlike our task 4, where the exposure to ambiguity is fixed by the experimenter, in their design subjects can reduce exposure to ambiguity by choosing portfolios with payoffs less dependent on the ambiguous states.
Baillon & Bleichrodt (2015) propose choices between a binary lottery and a binary act, for different known probabilities of the lottery outcomes and the same level of ambiguity of the act. From these choices, they elicit the matching probabilities, respectively for an event and its complement, making the subject indifferent between the lottery and the act.
Cubitt *et al.* (2018) propose an experiment where each subject's ambiguity sensitivity is measured by an ambiguity premium, a concept analogous to and comparable with a risk premium. As in our design and in the one of Chakravarty & Roy (2009), also in their design some tasks feature choice under risk and others choice under ambiguity. With this approach, they are able to calculate ambiguity premia within KMM. A distinctive feature of this approach is the estimation of each subject's subjective beliefs about the uncertainty in ambiguous tasks. Differently, we adopt a more qualitative approach to testing, as also Halevy (2007), Baillon & Bleichrodt (2015), and the following study do.
Cubitt *et al.* (2019) use specially constructed decks of cards, divisible into the four standard suits. Subjects are told that there would be equal numbers of black and red cards in each deck, but not exactly how the black cards would subdivide into clubs and spades, nor how the red cards would subdivide into hearts and diamonds. In each case, the compositions are determined by drawing from a bag containing two types of balls, the relative proportions of which are unknown to subjects. This approach differs from the one by Baillon & Bleichrodt (2015) by its use of indifferences expressed on a monetary scale, rather than on a probability scale, to indicate preferences. A key feature of their design is the possibility to manipulate whether the compositions of black cards and red cards are mutually dependent or mutually independent. A feature that might turn useful to analyze an extension of our study that we propose in the Conclusions, namely one in which also

the Instructions) "Immediately after having privately paid all subjects' earnings, the experimenter will go through the charity's website indicated by each subject at the beginning of phase B, make the on-line donation and fill in the donation screen with the identity of the donor; the email confirmation of the electronic donation will be privately forwarded by the experimenter to the subject within 24 hours after the end of the experiment, so as to account for possible delays due to any charity's website problems."

bonds are ambiguous, with this ambiguity correlating with the one of annuities.

(A.2) *Order treatment.* As in Halevy (2007), we also implement an order treatment. The goal is to check whether subjects' elicited ambiguity attitude is influenced by either presenting ambiguous tasks before unambiguous ones—task 2 (4) before task 1 (3)—and/or presenting choice-ambiguity tasks (3 and 4) before value-ambiguity tasks (1 and 2).[17]

(A.3) *Avoidance of subject's suspicion on the composition of the ambiguous urns.* An important issue raised in the experimental literature about Ellsberg-type tasks is subjects' thinking about strategic behavior and/or manipulations by the experimenter (see Schneeweiss 1973, Kadane 1992). To prevent the possibility that subjects might suspect they can be tricked on computer-generated realizations of random processes, we implement a combination of three features. First, for the each of the three ambiguous tasks (phase A task 1, phase A task 2, and phase B period 1), we determine the yellow-blue balls composition of the urn *prior* to the experiment, with independent random draws for each urn. Second, given the ambiguous task, subjects are assigned the same randomly generated urn composition. Third, at the beginning of the experiment we let each subject choose one of two colors (yellow or blue). The chosen color is associated to the highest of the two outcomes for each lottery that the subject would play in the experiment with a computerized urn with yellow and blue balls. The fact that the chosen "winning" color is not the same for all subjects should prevent the possibility of strategic manipulations of the computer-generated realization by the experimenter.

(A.4) *Minimization of across-task contamination in phase A.* Although subjects are told that phase A is made of four tasks, as in Halevy (2007) and Attanasi *et al.* (2014) instructions of a new task are given and read aloud only prior to that task.

(A.5) *Minimization of across-task and across-phase hedging behavior against ambiguity (see,* e.g.*, Bade 2015).* During and at the end of phase A, subjects know nothing about the composition of the ambiguous urns of tasks 2 and 4: the random draws for phase A are performed only at the end of the experiment. This prevents subjects from making any updating about the actual composition of the second ambiguous urn shown in phase A (task 4 in the main treatment and task 2 in the order treatment) and of the ambiguous urn of phase B. Moreover, such updating would be meaningless, since the random draws determining the composition of the three ambiguous urns have been *independently* performed before the experiment.

Several **design issues of phase B** deserve to be discussed:

(B.1) *Simpler decision problem.* In the experiment, the labels "annuity" and "bond" are never used in the instructions, so as to avoid framing effects. We use the more neutral wording "invested amount" and "amount not invested", respectively. This, coupled with a return on bonds set equal to 1 in the experiment, allows us to present the subjects with a simple investment problem where the invested amount a is the demand for annuities and

[17]The only significant order effect found in Halevy (2007) with four randomized orders of urns is that the task presented as first received a significantly lower reservation price than under alternative orders in which this urn was not the first, independently of the task. Therefore, we thought that having a "value & unambiguous"task shown at first in the main treatment (as in Halevy 2007) and the opposite (in both type and information) "choice & ambiguous"task shown at first in the order treatment would have represented the right counterbalance.

the amount not invested $(10 - a)$ is the demand for bonds. The fact that the demand for bonds is a pure transfer of the initial endowment from period 1 to period 2 is without loss of generality, given that in the general version of the annuity-bond trade-off problem, the return on bonds is independent of whether the subject is "alive" (active) or not in period 2 (see d'Albis & Thibault 2018). Furthermore, the experimental implementation of the three periods of phase B is in line with the return on bonds being set equal to 1. In fact, the time lag between period 1 and period 2 is very short (period 2 starts immediately after the end of period 1). Same is for period 2 and period 3 (bequest implementation): the experimenter implements the subject's bequest immediately after the end of the experiment, and the bequest receipt is sent to the subject within 24 hours (same short time lag between bequest decision and bequest implementation for all subjects in the experiment). As a final remark on this point, we acknowledge that this "invest" *vs.* "not invest" frame might induce an experimenter demand effect: experimental subjects could see in the act of commission (invest) rather than in the act of omission (not invest) cues that the former constitutes appropriate behavior. However, as Zizzo (2010) correctly states, the experimenter demand effect is a potential problem only when it is positively correlated with the true experimental objectives predictions. And, in our case, the effect goes against under-annuitization, which is our prediction in Section 2 for ambiguity-averse subjects.

(B.2) *Bequests as charity donations.* In the model of Section 2, the subject's voluntary bequest x is the money donated to the next generation if "alive" in period 2, and the involuntary bequest $(10 - a)$ is the money left to it if not "alive" in period 2. The subject's warm-glow intergenerational altruism is captured by $h(x)$ and $h(10 - a)$, respectively in the case where he/she is alive or not alive in period 2. Recall that warm glow is a necessary condition to obtain under-annuitization (see Yaari 1965, and Davidoff *et al.* 2005), which is the main object of our study. To induce a positive $h(\cdot)$ the experimental implementation, we try to relate the bequest's receiver (outside the experiment, in period 3 of phase B) to the donor (in the experiment, in period 2 of phase B). In particular, we let subjects in the experiment indicate—before knowing the decision problem in phase B—a charity as bequest recipient.[18] The fact that the subject's bequest is implemented—immediately after the experiment—by the experimenter (who provides the subject with the charity donation receipt) guarantee ex-post check of bequest implementation. Finally, the charity-related questionnaire allows us to measure, among other things, the subject's links with the chosen charity and thereby his/her level of warm-glow altruism toward it.

(B.3) *Strategy method for voluntary bequest elicitation.* In a life-cycle framework theoretically analyzed in Section 2, the voluntary bequest choice x is made in period 2, and only if the subject is "alive," *i.e.*, active, in period 2. However, following a widely-used method in experimental economics, in the experiment each subject is asked to choose x before period 2. This allows us to elicit x also for those subjects who will not be active in period 2, due to an unfavorable random draw at the end of period 1.[19]

[18]We decided not to involve a subject's relative or friend as bequest receiver, mainly for two reasons: first, it would not have been possible to check ex-post the exact sharing of the subject's bequest between his/her relative or friend and him/herself; second, measuring the subject's altruism toward a relative or friend would have lead to similarly high levels of elicited altruism in the subject pool, with no heterogeneity in the distribution of this idiosyncratic feature.

[19]Notice that, in terms of Yaari's (1965) and Davidoff *et al.* (2005), $(10 + a - x)$ is the subject's

(B.4) *Control questions.* The two sets of four control questions about the decision problem in phase B are aimed at identifying subjects for whom we are sure that they have not perfectly understood the rules and/or the structure of payoffs of the decision problem in phase B. We include in this group all subjects that have made at least 1 mistake in the first set and at least 1 mistake in the second set of 4 control questions. Although these subjects are allowed to participate in the two-period investment-donation decision problem, we do not consider them in the data analysis of phase B (Section 4.4).

Finally, our **Payment protocol** deserves some comments:

(P.1) *Random-lottery incentive mechanism and accumulated earnings.* In phase A, only one of the four tasks is randomly selected at the end of the experiment to determine subjects' earnings in that phase. Here we adopt a random-lottery incentive mechanism—extensively used in economic experiments (see the survey in Cox *et al.* 2015)—with the twofold goal of obtaining no wealth effect between different tasks of phase A, and proposing bigger stakes to experimental subjects. Furthermore, in order to let subjects focus separately on each phase of the experiment, we paid earnings of both phase A and phase B, thorugh two independent random draws. This payment protocol should have minimized potential distortions linked to the random-lottery incentive mechanism in phase A, in line with recent findings in the experimental literature (Cox *et al.* 2015).

(P.2) *Phase A proposed before but paid after phase B.* We propose to subjects phase A always *before* phase B, so as to avoid investment and bequest decisions in phase B being distorted by weird expectations about what will be the experimental task(s) in subsequent phase A. However, we pay phase A always *after* subjects go through and are paid for phase B, so as to minimize wealth effects (*e.g.*, heterogeneity of previously collected earnings) on behavior in phase B.[20]

3.3 The experimental hypotheses

In this section, first we show how the four tasks of phase A can be used to detect the sign of a subject's ambiguity attitude within the KMM model. Then, building on the theoretical model introduced in Section 2, we derive two experimental hypotheses for phase B on, respectively, the impact of a subject's elicited ambiguity attitude in phase A on his/her investment in annuities in period 1, and the effect of the latter on his/her donation to the charity in period 2.

consumption if alive in period 2. However, the labels "bequest", "consumption" and "alive" are never used in the instructions, again to avoid framing effects. We use the more natural wording "amount donated to the charity" for x, "amount kept by the subject" for $(10 + a - x)$, and "active" rather than "alive".

[20]We acknowledge that wealth effects might not have been fully eliminated by design, since during phase B subjects can expect positive earnings from phase A. If this were the case, then the restriction to *constant ambiguity aversion* in the KMM model (see KMM, p. 1876) would be more suited to the theoretical analysis of the ambiguous tasks in phases A and B. However, in Extension 2 of Online Appendix A we show that, *ceteris paribus*, the demand for annuities of an ambiguity-neutral subject increases in the additional endowment earned from phase A. Given that this additional endowment cannot be invested in phase B and is earned both if active and if not active in period 2 of that phase, the intuition leans towards a higher demand for annuities independently of the ambiguity attitude.

3.3.1 Elicitation of ambiguity attitudes in phase A

Recall that we use KMM's smooth ambiguity model as a general framework. Therefore, as we already made for the theoretical framework of Section 2 implemented in phase B, we assume that also in phase A the subject's preferences are represented by the von Neumann-Morgenstern Expected Utility function (henceforth, EU) for simple lotteries, and we relax reduction between first and second-order probabilities in two-stage lotteries in order to account for multiplicity/uncertainty of the possible compositions of the second-stage lottery.

Each task of phase A (see Section 3.2.1) concerns two-outcome lotteries, *i.e.*, with $\overline{x}, \underline{x} \in \mathbb{R}_+$, $\overline{x} > \underline{x}$. The urns with unknown composition of tasks 2 and 4 are represented by the 10-ball one-stage lottery $\widetilde{l}_\theta \sim (\overline{x}, p_\theta; \underline{x}, 1 - p_\theta)$, where $p_\theta = \theta/10$ is the first-order probability given by the (unknown) ratio of the number of yellow balls $\theta \in \{0, 1, ..., 10\}$ over 10 yellow and blue balls. The second-order probabilities over the composition of the 10-ball urn are q_θ, with $\theta \in \{0, 1, ..., 10\}$, in both task 2 and task 4.

With this in mind, urns with unknown composition of tasks 2 and 4 can be modelled as a two-stage lottery L^t for $t \in \{2, 4\}$, where the second stage is represented by a set of 11 lotteries $\widetilde{l}_\theta \sim (\overline{x}, p_\theta; \underline{x}, 1 - p_\theta)$, with $\overline{x} > \underline{x}$, and $\theta \in \{0, 1, ..., 10\}$. The first stage is represented by the lottery L^t having as possible outcomes the 11 second-stage lotteries $\widetilde{l}_\theta$ with probabilities $(q_0, ..., q_{10})$. These are the second-order probabilities over the plausible probability distributions for $\widetilde{l}_\theta$.

Following KMM, the subject's ex-ante utility is measured, in tasks $t \in \{1, 2, 3, 4\}$, by:

$$u(CE(L^t)) = \phi^{-1}\left(\sum_{\theta=0}^{10} q_\theta \phi(EU(\widetilde{l}_\theta))\right) \tag{9}$$

with

$$EU(\widetilde{l}_\theta) = p_\theta u(\overline{x}) + (1 - p_\theta) u(\underline{x}). \tag{10}$$

Function u is a von Neumann-Morgenstern utility function, and ϕ captures the subject's smooth ambiguity attitude. In fact, ϕ is a von Neumann-Morgenstern index function accounting for the attitude toward mean preserving spreads in the induced distribution of the expected utility of the one-stage lottery conditional to θ, namely $EU(\widetilde{l}_\theta)$. KMM show that "smooth ambiguity aversion" is equivalent to ϕ being concave. Therefore, it is equivalent to aversion to mean preserving spreads of the expected utility values induced by the second-order subjective probability and lottery $\widetilde{l}_\theta$. Then, defining function v as $v = \phi \circ u$, the certainty equivalent of the two-stage lottery of tasks $t \in \{1, 2, 3, 4\}$ is:

$$CE(L^t) = v^{-1}\left(\sum_{\theta=0}^{10} q_\theta v(CE(\widetilde{l}_\theta))\right), \tag{11}$$

where $CE(\widetilde{l}_\theta)$ is the certainty equivalent of the one-stage lottery conditional to θ. Function v is a von Neumann-Morgenstern index function accounting for the attitude toward mean preserving spreads in certainty equivalents of the one-stage lottery conditional to θ, namely $CE(\widetilde{l}_\theta)$ (see KMM 2005, p. 1855).

Note that the simple lottery of task 1 is analogous to a two-stage lottery with all second-stage lotteries $\widetilde{l}_\theta$ being L^1, and objective first-order probability $p_\theta = 1/2$ for each $\theta \in \{0, 1, ..., 10\}$. Therefore, Eqs. (9) and (11) collapse to $CE(L^1) = u^{-1}(EU(l_{\theta=5}))$, with $EU(l_{\theta=5}) = 0.5(u(20) - u(0))$ from Eq. (10). The same holds for the ten simple lotteries of task 3 where, for each $j = 1, 2, .., 10$, the simple lottery L^3_j is analogous to a two-stage lottery with all second-stage lotteries $\widetilde{l}_\theta$ being L^3_j, and, independently of j, $p_\theta = 1/2$ for each $\theta \in \{0, 1, ..., 10\}$. Therefore, for each $j = 1, 2, .., 10$, Eqs. (9) and (11) collapse to $CE(L^3_j) = u^{-1}(EU(l_{\theta=5}))$, with $EU(l_{\theta=5}) = 0.5(u(\overline{x}_j) - u(\underline{x}_j))$ from Eq. (10).

With all this in mind, by looking at the subject's behavior in tasks 1-4, we can identify whether a subject shows aversion, neutrality or proneness to ambiguity within KMM. Let us first compare behavior in tasks 1 and 2.

In tasks 1 and 2, the subject is asked to *value*, respectively, the unambiguous lottery L^1 and the ambiguous lottery L^2 with the same expected probability for the two outcomes of the second-stage lottery. In fact, the principle of insufficient reason suggests that the subject believes that each urn composition in task 2 is equally likely, as it actually was in the random composition of the urns prior to the experiment. Therefore, $q_\theta = 1/11$ for each $\theta \in \{0, 1, ..., 10\}$ because of the assumption of uniform distribution.[21] Then, the third-order probabilities on parameter p yields $E(p) = 1/2$. As the two second-stage lotteries of tasks 1-2 have the same pair of outcomes $(\overline{x}, \underline{x}) = (20, 0)$, their variety only depends on first-order probabilities. Thus, ambiguity aversion yields $CE(L^2) < CE(L^1)$ in Eq. (11).

In Section 3.2.1 we called X^t the lowest sure amount for which a subject prefers option Right to option Left in task $t \in \{1, 2\}$. This Left-to-Right switching amount determines an interval estimate for the certainty equivalent of lottery $CE(L^t)$ in task $t \in \{1, 2\}$: the greater X^t, the higher his/her estimated certainty equivalent. With this in mind, the following operational definition of ambiguity attitude within KMM can be introduced.

Definition 1 ***(value-ambiguity attitude)***
A value-ambiguity-averse (loving) subject values an ambiguous lottery less (more) than its unambiguous equivalent with the same mean probabilities. Then, this subject shows value-ambiguity aversion if $X^2 \leq X^1$, value-ambiguity neutrality if $X^2 = X^1$, and value-ambiguity proneness if $X^2 \geq X^1$.

In short, a value-ambiguity-averse subject values an ambiguous lottery less than its unambiguous equivalent with the same mean probabilities. In the KMM model, this is true if the subject's ϕ function is concave.

Our experimental design offers an alternative to elicit ambiguity attitude by comparing the subject's behavior in tasks 3 and 4. In tasks 3 and 4, the subject is asked to make a *choice*, respectively, among ten unambiguous lotteries L^3_j and among ten ambiguous lotteries L^4_j, for $j = 1, 2, .., 10$. Given j, the pair of outcomes $(\overline{x}^t_j, \underline{x}^t_j)$ is the same for $t \in \{3, 4\}$, and—under the principle of insufficient reason—, in task 4 second-order probabilities $q_\theta = 1/11$ for each θ and the expected probability for the two outcomes of the second-stage lotteries L^4_j is $E(p) = 1/2$, the same as the objective probability of the two outcomes of the simple lottery L^3_j. Therefore, ambiguity aversion yields $CE(L^4_j) < CE(L^3_j)$

[21] See also Attanasi *et al.* (2014), who find that subjects' elicited beliefs about the unknown composition of the 10-ball ambiguous urns of their "unknown" treatment are uniformly distributed.

in Eq. (11) for each $j = 1, 2, .., 10$. Defining a dispersion order $\succ$ on the set of lottery indexes $\{1, 2, ..., 10\}$, such that $10 \succ ... \succ 2 \succ 1$, a more dispersed lottery is equivalent to a portfolio containing a larger share invested in the risky asset.

In Section 3.2.2 we called j_t^* the subject's chosen line in task $t \in \{3, 4\}$. The chosen line determines the dispersion (outcome spread) of the lottery $L_{j^*}^t$ played in task $t \in \{3, 4\}$: the greater the index j_t^* ($j_t^* = 1, 2, ..., 10$ for each t), the greater the dispersion of $L_{j_t^*}^t$. With this in mind, the following definition can be introduced.

Definition 2 ***(choice-ambiguity attitude)***
A choice-ambiguity-averse (lover) subject chooses a less (more) risky lottery when the probability distribution over lottery outcomes is ambiguous, with the same mean probability. Then, this subject shows choice-ambiguity aversion if $j_4 \leq j_3$, choice-ambiguity neutrality if $j_4 = j_3$, and choice-ambiguity proneness if $j_4 \geq j_3$.

As anticipated above, in the KMM framework, "smooth ambiguity aversion" is shown to be equivalent to the concavity of the von Neumann-Morgenstern index function ϕ accounting for the attitude toward mean-preserving spreads in the induced distribution of the expected utility of the one-stage lottery conditional to the—in our experiment, 11—possible compositions of the unknown lottery. Gollier (2014) has shown that it is not true in general that the concavity of the ϕ function (value-ambiguity aversion) implies the choice-ambiguity-aversion of the subject. In other words, a value-ambiguity-averse subject could choose a lottery with greater outcome spread when probabilities are unknown (task 4) than when they are known (task 3).

However, Gollier (2014) provides sufficient conditions on the structure of the two-stage uncertainty to re-establish the link between the concavity of ϕ and ambiguity aversion. One of these sufficient conditions is that the different second-stage distributions of the lottery outcomes can be ordered by the Monotone Likelihood Ratio stochastic order.[22] Referring to the ten lotteries L_j^t with $j = 1, 2, .., 10$ in tasks $t = 3, 4$, the set of distributions of outcomes $\left\{(\overline{x}_j^t, p_\theta; \underline{x}_j^t, 1 - p_\theta) \,|\theta = 0, ..., 10\right\}$ in the ambiguous task $t = 4$ can always be ordered by the Monotone Likelihood Ratio, for each $j = 1, 2, ..., 10$.[23] Thus, we conclude that, in the smooth ambiguity framework of KMM, the two operational definitions of value-ambiguity attitude and choice-ambiguity attitude are equivalent in the four tasks of phase A, and are satisfied if ϕ is concave. This justifies the following definition, which combines Definitions 1 and 2.

Definition 3 ***(coherent-ambiguity attitude)***
A subject is coherent-ambiguity-averse if $X^2 \leq X^1$ and $j_4^* \leq j_3^*$, with at least one of the two relations holding strictly; coherent-ambiguity-neutral if $X^2 = X^1$ and $j_4^* = j_3^*$; coherent-ambiguity-loving if $X^2 \geq X^1$ and $j_4^* \geq j_3^*$, with at least one of the two inequalities holding strictly.

[22] The *monotone likelihood ratio property* is a property of the ratio of two probability density functions. Formally, distributions $f(x)$ and $g(x)$ bear the property if for every $\overline{x} > \underline{x}$, $f(\overline{x})/g(\overline{x}) \geq f(\underline{x})/g(\underline{x})$, that is, if the ratio is nondecreasing in the argument x.

[23] In particular, they can be ordered from higher to lower θs. Start with $f(x) = (\overline{x}_j^4, p_{10}; \underline{x}_j^4, 1 - p_{10})$ and $g(x) = (\overline{x}_j^4, p_9; \underline{x}_j^4, 1 - p_9)$. Then, independently of j, $f(\overline{x}_j^4)/g(\overline{x}_j^4) \geq f(\underline{x}_j^4)/g(\underline{x}_j^4)$ since $(1/0.9) > (0/0.1)$. The same holds for every θ such that $f(x) = (\overline{x}_j^4, p_\theta; \underline{x}_j^4, 1 - p_\theta)$ and $g(x) = (\overline{x}_j^4, p_{\theta-1}; \underline{x}_j^4, 1 - p_{\theta-1})$.

Therefore, our operational definition of coherent-ambiguity attitude in the smooth ambiguity framework is based on a double-check: we compare the subject's decisions in task 1 *vs.* task 2 and in task 3 *vs.* task 4. The first comparison tells us whether, given the two second-stage lottery-outcomes, he/she prefers to know first-order probability p than facing a mean-preserving spread of second-order probabilities over the all possible discrete probabilities $\widetilde{p} \in \{0, 0.1, ..., 0.9, 1\}$. The second comparison tells us whether he/she prefers a less risky lottery (a less dispersed performance of the portfolio where this mean-preserving spread takes place). An ambiguity-averse subject should show both these preferences.

3.3.2 Effects of elicited ambiguity attitudes on behavior in phase B

A **first auxiliary assumption** is needed in order to link the subject's sign of ambiguity attitude—aversion, neutrality, and proneness— elicited in the *ambiguous* portfolio decision tasks of phase A, with the subject's sign of ambiguity attitude towards *ambiguous* survival probabilities in period 1 of phase B. Note that, to simplify notation, for both kinds of ambiguity attitudes, we use the same symbol ϕ to indicate the von Neumann-Morgenstern index function accounting for ambiguity attitude within KMM.

The former interpretation is more standard (see Eqs. (9-11) in Section 3.3.1), since it accounts for the attitude toward mean preserving spreads of the expected utility values induced by the second-order subjective probabilities of a two-stage lottery. In fact, we assume $\phi = v \circ u^{-1}$, with u being the von Neumann-Morgenstern utility of the one-stage lottery, and v being a von Neumann-Morgenstern index function accounting for the attitude toward mean preserving spreads in certainty equivalents of the one-stage lottery with unknown probabilities (see KMM 2005, p. 1855).

The latter formulation is instead a more complicated mathematical object (see Eqs. (3-4) in Section 2). In fact, it accounts for the attitude toward mean preserving spreads in the induced distribution of the lifetime expected utility conditional to the unknown survival probability $\widetilde{p}$. In fact, the lifetime expected utility is state-dependent (see Eq. (3)), thus it is not possible to model the expected utility of the two-stage ambiguous lottery with the standard composition of v and u. In fact, the utility of the one-stage lottery outcome if alive in period 2 includes both the subject's utility of money kept for him/herself, $g(\cdot)$, and the subject's warm glow from the (voluntary) donation to the charity, $h(\cdot)$. The utility of the one-stage lottery outcome if not alive in period 2 is only made by $h(\cdot)$, which measures the warm glow from the (involuntary) donation to the charity.

A feature of the experimental design provides support to this assumption. In fact, we set possible outcomes and probabilities in each of the four tasks of phase A such that the ex-ante (*i.e.*, before making the decision) expected value of a subject's earnings in phase A is equal to the ex-ante expected value of the sum of his/her earnings and of the charity's earnings in phase B. In fact, the subject's ambiguity attitude in phase A is elicited for the same interval of lottery outcomes of the investment-donation decision problem he/she faces in phase B. More precisely, the ten lottery outcomes of task 4 of phase A represent the ten possible pairs of outcomes $(10+a, 10-a)$ for each positive annuitization in period 1 of phase B ($a \in \{1, 2, ..., 10\}$). In fact, choosing lottery L_j^4 in task 4 means choosing to play lottery $(10+j, \widetilde{p}; 10-j, 1-\widetilde{p})$, with ($j \in \{1, 2, ..., 10\}$). For $j = a$, this is equivalent to choosing to play lottery $(10+j, \widetilde{p}; 10-j, 1-\widetilde{p})$ at the beginning period 2 of phase B.

Therefore, selecting the first (resp., the last) of the ten lotteries of task 4 is equivalent to setting $a = 1$ (resp., $a = 10$).

With all this, we elaborate the first auxiliary hypothesis as follows:

H0.i [***Correlation between different kinds of ambiguity attitudes***] Aversion (proneness) to ambigous returns in the portfolio decision tasks of phase A is positively correlated with aversion (proneness) to ambiguous survival probabilities in the investment-donation decision problem of phase B.

The main consequence of this hypothesis is that we can use the subject's ambiguity attitude elicited in phase A as a proxy of his/her ambiguity attitude toward ambigous survival probabilities in phase B, thereby testing the theoretical predictions elaborated in Section 2 about the subject's behavior in phase B. Another important consequence is that a different behavior between task 4 of phase A and period 1 of phase B can be ascribed to a positive bequest x in the latter, *i.e.*, to the subject's warm-glow altruism. In fact, this reduces the two lottery outcomes to $(10 + a - x, 0)$ for the subject and increases them to $(x, 10 - a)$ for the charity he/she has previously indicated.

Recall that the subject's warm glow is a necessary condition for under-annuitization to occur (see Yaari 1965). Then, a **second auxiliary assumption** is formulated to assess that the voluntary donation increases with the investment in annuities. This assumption relies on Proposition 1.ii (see Section 2), which in turn assumes that the subject's warm-glow altruism, $h(\cdot)$, is positive and increasing in the donation to the charity. However, since also the subject's utility of money kept for him/herself if active, $g(\cdot)$, is assumed to be positive and increasing in his/her private earnings from phase B, also the share of wealth he/she keeps as private earnings if alive should increase with the investment in annuities. In fact, annuities are especially attractive because of a higher private consumption if alive. Therefore, a positive correlation between the amount invested by the subject in period 1 and amount kept for him/herself if active in period 2 is a necessary condition for the framework introduced in Section 2 to stand.

All this is formally stated in the second auxiliary hypothesis:

H0.ii [***Annuity over Consumption and Bequest in period 2***] If active in period 2, both the voluntary donation x and the amount kept by the subject as his/her private earning in phase B, $(10 + a - x)$, are higher for higher invested amounts in period 1.

In Section 4.3 we will show how the subject's declared links to the chosen charity (charity-related questionnaire) are crucial features for us to detect his/her actual warm-glow altruism from voluntary donation to this charity. In fact, while the second part of H0.ii (positive relation between annuity returns and period 2 consumption) holds for both selfish and non-selfish subjects, the first part (positive relation between annuity returns and period 2 donation) only holds—see eq. (7)—for a sufficiently high level of warm-glow altruism $h(\cdot)$ involved by the voluntary donation x.

We know elaborate the two experimental hypotheses that we test in the next section. The first hypothesis concerns behavior in period 1 of phase B and is the most important for the goal of the paper. It directly comes from Proposition 2 of Section 2. It uses the behavior in phase A both to detect at a within-subject level coherence with the KMM model (see Definition 3 in Section 3.3.1), and as a proxy of subjects' attitude toward the ambiguous survival probabilities of phase B (auxiliary assumption H0.i).[24]

The hypothesis is elaborated in terms of a between-subject comparison.

H1 [***Ambiguity over investment in annuity in period 1***]. Consider the coherent-ambiguity attitudes elicited in phase A. The invested amount a in period 1 of phase B is significantly lower (resp., higher) for a coherent-ambiguity-averse (resp., loving) subject than for a coherent-ambiguity-neutral subject.

The second hypothesis concerns behavior in period 2 of phase B and is made of two parts. The first part combines Proposition 2 and Proposition 1.ii (see Section 2). We see it as a test of independence between a subject's warm-glow giving and his/her ambiguity attitude. Indeed, assuming similar distributions of sensitivities to warm-glow giving across different signs of ambiguity attitude— aversion, neutral, and proneness—, by Proposition 1.ii we should find that the average voluntary donation and amount kept by the subject (both considered in absolute terms) should both increase with a, the investment in annuity. By Proposition 2, this investment is lower (higher) for an ambiguity-averse (ambiguity-loving) than for an ambiguity-neutral subject. The second part of the hypothesis directly comes from Proposition 1.i: having uncertainty about "survival" been resolved between period 1 and period 2, a subject active in period 2 should not rely on his/her ambiguity attitude when choosing how to distribute his/her total wealth $(10 - a)$ among voluntary donation x and his/her private earnings $(10 + a - x)$.

H2 [***Ambiguity over wealth allocation in period 2***] If active in period 2, both the voluntary donation x and the amount kept by the subject as his/her private earning $(10 + a - x)$ are lower (higher) for an ambiguity-averse (ambiguity-loving) than for an ambiguity-neutral subject. Conversely, the share of wealth if active used for the voluntary donation, *i.e.*, $x/(10 - a)$, and the complementary share kept by the subject as his/her private earning in phase B, *i.e.*, $(10 + a - x)/(10 - a)$, are independent of the subject's ambiguity attitude.

4 Data analysis

In this section, first we report the distribution of subjects according to the elicited sign of ambiguity attitude in phase A. Then, we report raw statistics on the chosen charity and on answers to the charity-related questionnaire before phase B. Finally, we test the two experimental hypotheses about phase B, elaborated in the previous section, namely H1 and H2.

[24]Note that we elaborate and test predictions that only rely on the elicited sign of the ambiguity attitude—aversion, neutrality, or proneness—rather than on the elicited degree of ambiguity aversion. In fact, as Attanasi *et al.* (2018) have shown for elicited risk attitudes across different tasks and Attanasi *et al.* (2014) have confirmed for elicited ambiguity attitudes across different tasks, while the elicited degrees of risk and ambiguity aversion are usually significantly different across tasks, the elicited signs of the two attitudes are not. This should contribute to minimize both the well-known problem of observed heterogeneity of estimates across experimental tasks (Crosetto & Filippin 2016), and the equally important problem of preference reversal for ambiguity aversion reported in Trautmann *et al.* (2011). The latter problem is also minimized by proposing choice and evaluation tasks sequentially, and distributing instructions of each new task only prior to that task (see comments A.4 and A.5 in Section 3.2.3 on these issues).

4.1 Elicited ambiguity attitudes in phase A

Figure 1 reports the distribution of elicited ambiguity attitudes of the 100 subjects according to their behavior in phase A. The left panel reports value-ambiguity attitudes (see Section 3.1, Definition 1: task 2 *vs.* task 1), the central panel reports choice-ambiguity attitudes (Definition 2: task 4 *vs.* task 3), the right panel reports coherent-ambiguity attitudes (Definition 3: coherence of definitions 1 and 2).

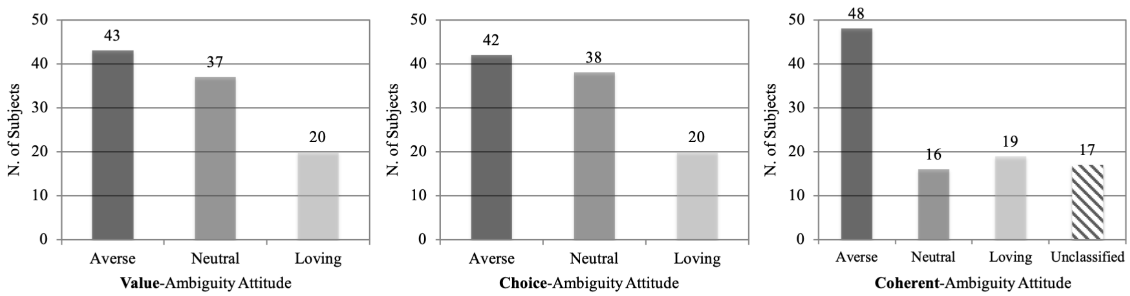

Figure 1. Distributions of value-ambiguity, choice-ambiguity, and coherent-ambiguity attitudes

In line with the results of Attanasi *et al.* (2014), the majority of the subjects (approximately 4/10) are ambiguity-averse, and only few of them (approximately 2/10) are ambiguity-loving, independently of the dimension (value or choice). Furthermore, and again in line with the previous study, we find that around half of the subjects show ambiguity aversion in at least one dimension (value or choice) and no ambiguity proneness in the other dimension. These subjects are coherent-ambiguity-averse. Consistently, around 2/10 subjects are coherent-ambiguity-loving (ambiguity-averse in at least one dimension and ambiguity non-averse in the other dimension). Only 16/100 subjects show neutrality to ambiguity in both dimensions. We find no significant treatment effect (reserve order of presentation of the four tasks) in the three distributions of Figure 1 (χ^2 test: *p-value* = 0.798 for value-ambiguity attitude, 0.606 for choice-ambiguity attitude, 0.320 for coherent-ambiguity attitude).

In the tests of H1 and H2, we do not consider the 17 unclassified subjects in the right panel of Figure 1 (7/50 in the control treatment, 10/50 when tasks 1-4 are presented in reverse order): these subjects show ambiguity aversion in one dimension and ambiguity proneness in the other one. Therefore, they did not pass our check of coherency of behavior within the smooth ambiguity framework of KMM. We call **KMM-coherent** the 83/100 subjects who passed the 4-task coherency test of phase A.

4.2 Identification of “rational” subjects in phase B

Here we look at the distribution of subjects according to the number of incorrect answers in the two sets of four control questions administered at the beginning of phase B. Those questions concerned the rules and/or the structure of payoffs of the decision problem of phase B. In the first set, 73/100 subjects made at least one mistake (40/73 made one mistake, 24/73 made two mistakes, 8/73 made three mistakes, 1/73 made four mistakes).

The 27/100 subjects who made no mistake in the first set of four control questions were allowed to skip the second set of questions. Among the remaining 73 subjects, only 7 made at least one mistake in the second set of control questions (only 1/7 made four mistakes).[25] As anticipated in Section 3.2.3, in the tests of H1 and H2 we do not consider these 7 subjects, since we are not sure that they perfectly understood the decision problem of phase B.

Considering together this group of 7 subjects and the group of 17 unclassified subjects in Figure 1, we get 22 subjects who showed either bounded rationality at the beginning of phase B and/or a non-KMM rationalizable behavior in phase A (2 subjects belonged to both groups). Therefore, when testing H1 and H2 in Section 4.4, we only consider the 78/100 subjects who showed full comprehension of the annuity-bequest problem of phase B *and* a behavior in phase A coherent with ambiguity attitude within KMM (*i.e.*, our reference model of subjects' ambiguity attitude in phase B). From now on, we call these subjects **rational-KMM-coherent**. However, we report in Online Appendix C robustness checks by considering the whole subject pool.

4.3 Charities and measures of warm-glow altruism

Figure 2 reports the distribution of chosen charities at the beginning of phase B. 55/100 subjects chose a well-known international charity (black color) and 40/100 a national charity (grey color).[26] Only 5/100 chose a local charity (light-grey color), *i.e.*, operating in a specific region of France.[27]

We see this as a methodological contribution of our study: the combined implementation of these three features—(*i*) charity chosen by the subject through a 5-minute web search; (*ii*) charity donation implemented by the experimenter through the charity's Website immediately after the experiment; (*iii*) E-mail confirmation of the donation individually sent by the experimenter to the subject within 24 hours by the end of the experiment—induced the subjects to choose well-known and reliable charities, offering an efficient and transparent Website donation system. This also reduced the heterogeneity of subjects' choices in terms of "next generation" as recipient of their donations in phase B.

Table C.1 in Online Appendix C reports the distribution of answers to the charity-related questionnaire administered after the choice of the charity, and to the final questionnaire. Recall that the charity-related questionnaire contained four items specific to the previously chosen charity, and two items on the general perception of others' and own altruism. The final questionnaire contained an item on self-assessed time discounting, and

[25]As for the high rate of wrong answers in the first set of control questions, we find no significant correlation with any of the subjects' idiosyncratic features. The only insight we find is in the experimental instructions wording. In fact, knowing that in the case of no mistake in the first set of questions one would skip the second set of questions might have motivated some subjects to voluntarily fail one of the four questions in the first set, so as to make additional training in the second set. This insight is supported by the fact that across the 73/100 subjects failing the first set of questions, 40/73 makes only one mistake and 24/73 makes two mistakes. Very few of them, 9/73, make more than two mistakes.

[26]Of these, 47 are French charities, one is in Burkina Faso (Association African Solidarité), one is in Italy (Caritas), and another one in Romania (Pretuieste Viata).

[27]The five local (French) charities are: Association Les Disciples (Strasbourg), Virade de l'Espoir (Morbihan), Association de l'Espérance des Nécessiteux en l'Amélioration du Futur (Strasbourg), De l'Eau pour l'Afrique (Grenoble), La Main du Coeur - Aide aux Enfants (Strasbourg).

items related to subjects' idiosyncratic features (gender, age, year and field of study). Table C.1 shows no significant difference for almost all these variables across the two types of chosen charities of Figure 2: international (55, black color), and national or local (45, grey or light-grey color), according to a Mann-Whitney equality-of-populations rank test (adjusted for ties). The same occurs if we compare the whole subject pool to the subgroup of 78 rational-KMM-coherent subjects on whom the tests of H1 and H2 in Section 4.4 will rely: our target group presents a distribution of answers not significantly different from the one of the whole sample of 100 subjects. Furthermore, the 78 rational-KMM-coherent subjects selected the same proportion of international, national and local charities—resp., 55.1% (43/78), 39.7% (31/78), and 5.1% (4/78)— shown for the whole sample of subjects in Figure 2. Therefore, we claim that our theory-driven selection of the target group of subjects did not distort the charity-related measurement of warm-glow altruism, and did not generate any bias in the distribution of elicited idiosyncratic features.

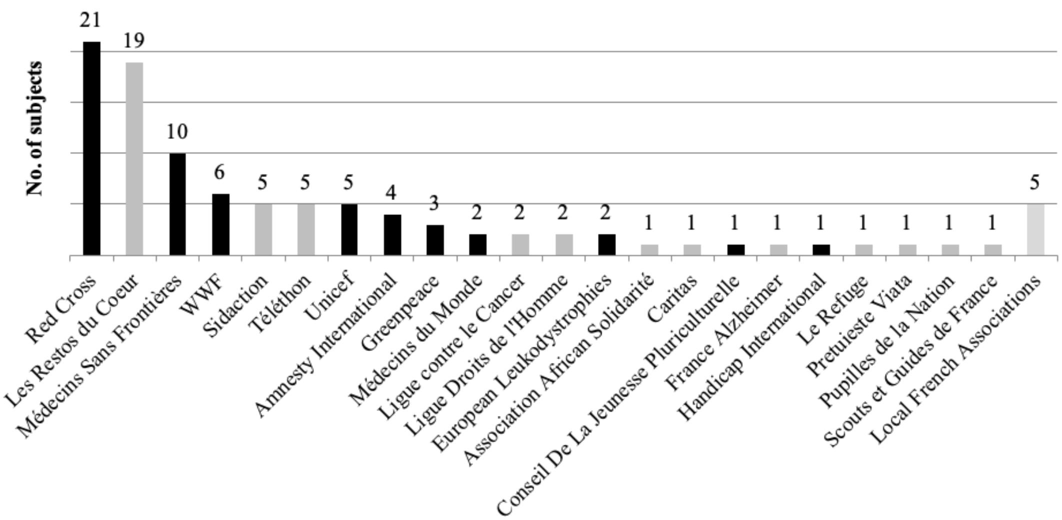

Figure 2. Distribution of subjects' chosen charities before the beginning of phase B

The four variables measuring subject's warm glow specific to the chosen charity indicates, respectively: the number of years the subject knew the chosen charity (*Charity Known Years*); how many times he/she previously donated to this charity (*Charity No. Previous Donations*); whether he/she ever participated in this charity's activities (*Charity Participation dummy*); whether any of his/her relatives or friends was directly concerned by this charity (*Charity Relatives-Friends dummy*). Answers to these four items show that: our experimental subjects knew the chosen charity since more than 3 years on average; 35% of them had already donated to the chosen charity; 25% of them participated in the activities of the chosen charity in the past; 25% of them had any of their relatives or friends directly concerned by the chosen charity. Furthermore, these four charity-related variables have low correlation indexes (highest Spearman's *rho* = 0.23).

The two variables measuring the subject's general perception of *others'* and *own altruism* take values from 0 to 10, according to their agreement with the statement that most of the time people try (resp., he/she tries) to help others rather than caring about themselves (resp., him/herself). Variable *Time Discounting* measures the amount of money (from €0 to €100) the subject declares to need in order to give up on spending €100 today and carry them over to the next year. Reported idiosyncratic features are gender (0 for male, 1 for female), age (categories 1-4: 18-19, 20-25, 26-30, 30-35 years old), graduate student dummy, economics student dummy. Finally, although not considered in our theoretical analysis, we also include as a control variable monetary risk aversion. In fact, the elicitation of the certainty equivalent of the lottery with known probabilities of task 1 provides an estimate of the subject's monetary risk attitude. Thus, we include the dummy *Risk Aversion* which takes value 1 if in task 1 if the Left-to-Right switching amount $X^1 \leq 9$ and 0 otherwise.

Notice that, for each of the above mentioned variables, including those measuring time discounting and risk attitude, we find no significant correlation with the ambiguity attitude elicited in phase A.

4.4 Test of experimental hypotheses

In this section, relying on the categorization of Sections 4.1–4.3, we test the two experimental hypotheses elaborated in Section 3.3.2 about subjects' behavior in the annuity-bequest decision problem of phase B.

We begin with preliminary checks. Note that H0.i is an auxiliary assumption that given the way it has been elaborated it cannot be tested. Therefore, we directly begin with the test of auxiliary assumption H0.ii. Figure 3 reports, in the left panel, subjects' private earnings (consumption) and voluntary donation (charity bequest) if active in period 2, for each invested amount (demand for annuities) in period 1. The left panel only refers to rational-KMM-coherent subjects, while the right panel refers to the whole subject pool. By looking at Figure 3, one can immediately notice that, as expected, the sub-sample of rational-KMM-coherent subjects is representative of the whole sample in terms of behavior in period 2 of phase B.

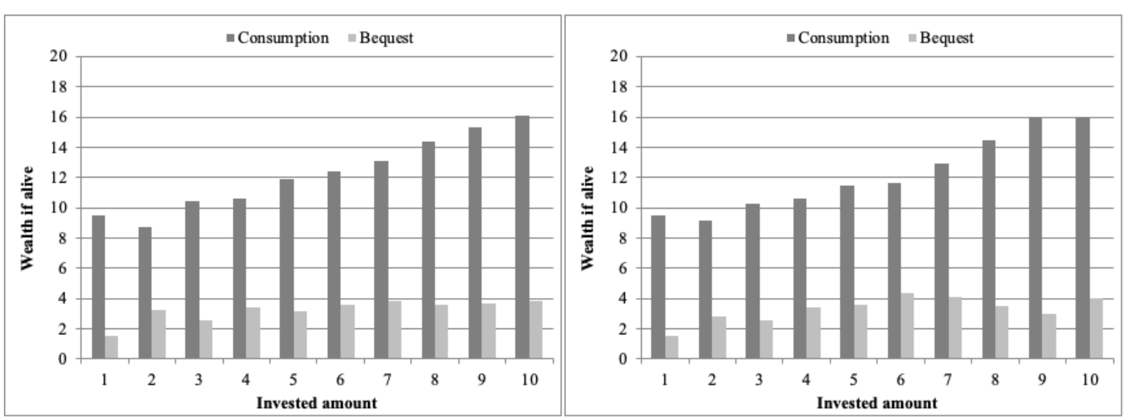

Figure 3. Subject's earnings and voluntary donations if active in period 2, by invested amount
Note: The left panel refers to rational-KMM-coherent subjects. The right panel refers to all 100 subjects.

The left panel of Figure 3 shows a positive correlation between consumption if alive in period 2 and demand for annuities in period 1 (Spearman's *rho* = 0.59, *p-value* = 0.000). However, the correlation between the latter and voluntary bequest in period 2 is not significant (Spearman's *rho* = 0.14, *p-value* = 0.216). The same holds if we consider the whole sample of subjects, in the right panel: Spearman's *rho* = 0.59 (*p-value* = 0.000) for the consumption, and Spearman's *rho* = 0.12 (*p-value* = 0.223) for the bequest. Therefore, H0.ii is verified for the money the subject decides to keep for him/herself, while it does not receive full support by Figure 3 as for the voluntary donation.

However, recall that warm glow is a necessary condition to obtain under-annuitization (see Yaari 1965, and Davidoff *et al.* 2005), and note that 15/100 subjects (14/78 rational-KMM-coherent subjects) donate nothing to the chosen charity if active in period 2. It is then reasonable to assume that the latter group of subjects does not satisfy the necessary condition of a positive sensitity to warm-glow giving (*i.e.*, $h(\cdot) > 0$ in the model of Section 2). Thus, in Table 2 we run two OLS regressions explaining voluntary donation as a function of the investment in annuities, by considering the whole sample of 100 participants (column "All Subjects" of Table 2) or only those with positive voluntary donation (column "Positive Warm Glow" of Table 2). Besides the invested amount in period 1 of phase B, we included as controls all the variables introduced at the end of Section 4.3. Obviously, we did not include the subject's ambiguity attitude elicited in phase A, since here we are testing H0.ii. In fact, H0.ii is an auxiliary assumption needed to elaborate H2. The latter regards the impact of the ambiguity attitude over the voluntary donation.

Dep. var.: Voluntary Donation	All Subjects		Positive Warm Glow	
Invested Amount	0.15 (0.13)		0.24 ** (0.12)	
Charity Known Years	0.16	(0.24)	–0.11	(0.25)
Charity No. Previous Donations	0.32	(0.26)	0.37	(0.25)
Charity Participation	–0.54	(0.76)	–0.08	(0.76)
Charity Relatives-Friends	–0.18	(0.74)	0.58	(0.73)
Altruism Own	0.13	(0.16)	0.13	(0.15)
Altruism Others	0.19	(0.18)	0.11	(0.18)
Risk Aversion	0.24	(0.61)	–0.27	(0.59)
Time Discounting	–0.01	(0.01)	0.00	(0.01)
Female	–0.15	(0.69)	–0.59	(0.66)
Age	0.08	(0.51)	–0.06	(0.47)
Economics	0.41	(0.67)	–1.37 **	(0.68)
Treatment	–0.84	(0.62)	–0.76	(0.59)
Constant	1.54 (2.20)		4.03 * (2.19)	
Adj. R-squared	-0.003		0.009	
No. of observations	100		85	

Table 2. OLS regressions explaining voluntary donation as function of the investment in annuities. *Note*: Standard errors in parentheses, * $p < 0.1$, **$p < 0.05$, *** $p < 0.01$

Results in Table 2 confirm that, if we only focus on subjects with $x > 0$ (Positive Warm Glow), then the investment in annuities a in period 1 has a significant positive impact on the voluntary donation x if active in period 2. The same does not hold if we consider the whole sample, supposedly because of the confound of including in the analysis subjects with $x = 0$. Note that none of the control variables has a significant effect on the voluntary donation, except for a significant negative effect of being a student in Economics when considering the whole sample. Also note that the same results of Table 2 hold if we consider the restricted sample of rational-KMM-coherent subjects (left panel of Figure 3).[28] Therefore, we conclude that **we find good support for H0.ii**.

We now move to the test of H1. Figure 4 reports in the left panel the distribution of subjects' demand for annuities (invested amount in period 1) of rational-KMM-coherent subjects. All subjects demand a positive amount of annuities, with 27% of them (21/78) investing half of their endowment and 19% of them (15/78) investing all their endowment (average investment = 57.4%). The fact that 77% (60/78) of subject invest at least half of their endowment in the annuity might be due to several features linked to our design. First, the absence of the possibility to consume the endowment in period 1, which would lead to a lower consumption in period 2 and to a lower demand for annuities in period 1 (see the theoretical Extension 1 in Online Appendix A). Second, our investment frame, with an act of commission (resp., omission) linked to the demand for annuities (resp., bonds) (see comment B.1 in Section 3.2.3). Third, a wealth effect coming from expectation of positive earnings from phase A (see comment P.2 in Section 3.2.3). Note that all these effects go against under-annuitization, that we aim to explain in our study. Thus, we interpret the finding of a negative relation between ambiguity aversion and annuitization shown in the right panel of Figure 4, which holds despite these effects, as a support for H1.

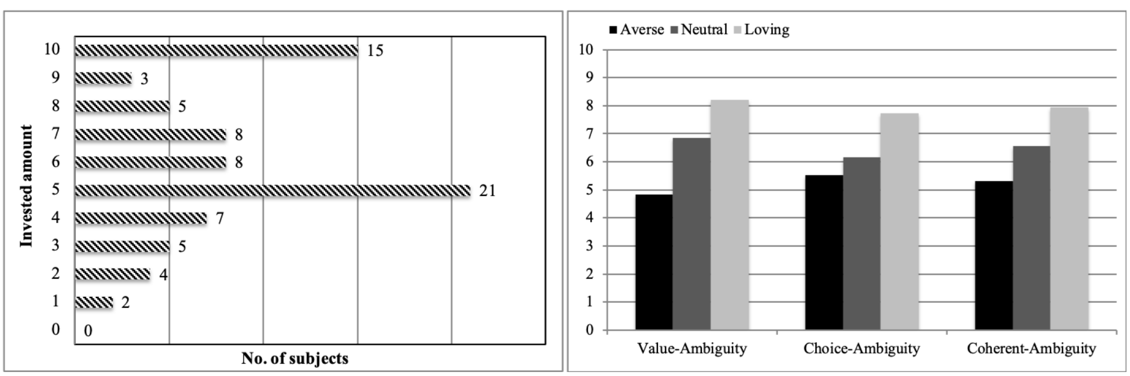

Figure 4. Frequency of invested amounts (left panel), and average invested amount by ambiguity attitude (right panel), for rational-KMM-coherent subjects

In the right panel, Figure 4 reports the average demand for annuities disentangled by the sign of the ambiguity attitude (aversion, neutrality, proneness) for rational-KMM-coherent subjects. A significantly different demand for annuities is found for the three categories of ambiguity attitudes, independently of whether we consider value-ambiguity,

[28] Relying on the literature of charitable giving (see, *e.g.*, Sargeant 2008), in Table C.2 of Online Appendix C we run an alternative test of H0.ii. We use the fact that a subject has chosen a national or local rather than an international charity as a feature of higher warm-glow altruism toward that charity for the same donation selected in period 2 of phase B. This alternative test basically confirms the results of Table 2.

choice-ambiguity, or coherent-ambiguity attitudes (Kruskal-Wallis test, *p-value* = 0.000, 0.060, and 0.001, respectively). Pairwise comparisons confirm a significantly lower demand for annuities by value-ambiguity-averse than by value-ambiguity-neutral subjects (Mann-Whitney test, *p-value* = 0.002). They also confirm a significantly higher demand for annuities by choice-ambiguity-loving than by choice-ambiguity-neutral subjects (Mann-Whitney test, *p-value* = 0.093). Finally, a significantly lower demand for annuities is found among ambiguity-averse than among ambiguity-loving subjects, independently from the dimension of ambiguity attitude (Mann-Whitney test, *p-value* = 0.000 for value-ambiguity, 0.018 for choice-ambiguity, and 0.000 for coherent-ambiguity).

To provide econometric support to the results shown in Figure 4, we run three regressions with the invested amount a in period 1 of phase B as dependent variable (see Table 3). Since $a \in \{0, 1, ..., 9, 10\}$, we rely on Tobit models, left censored at 0, and right censored at 10.[29] In each of the three models, the main regressor is a dummy for subject's coherent-ambiguity aversion. Model I considers as regressors also the charity-related items and the subject's general perception of own and others' altruism, all elicited in the charity-related questionnaire. Model II includes instead controls for individual characteristics elicited in the final questionnaire, for monetary risk aversion elicited in task 1 of phase A, and for treatment effects (due to the different order of presentation of the four tasks of phase A). Model III considers together all the above mentioned regressors.

Dep. var.: Invested amount	Model I	Model II	Model III
Coherent-Ambiguity Aversion	–2.52 *** (0.67)	–2.42 *** (0.67)	–2.53 *** (0.68)
Charity Known Years	–0.14 (0.23)	–	–0.14 (0.24)
Charity No. Previous Donations	0.01 (0.27)	–	–0.05 (0.27)
Charity Participation	–0.21 (0.81)	–	–0.74 (0.88)
Charity Relatives-Friends	0.51 (0.86)	–	0.53 (0.88)
Altruism Own	0.17 (0.18)	–	0.17 (0.18)
Altruism Others	–0.11 (0.17)	–	–0.16 (0.17)
Risk Aversion	–	–0.61 (0.66)	–0.65 (0.67)
Time Discounting	–	–0.01 (0.01)	–0.01 (0.01)
Female	–	0.39 (0.66)	0.46 (0.73)
Age	–	0.61 (0.51)	0.73 (0.57)
Economics	–	–0.01 (0.67)	–0.15 (0.71)
Treatment	–	–0.55 (0.67)	–0.25 (0.71)
Constant	7.79 *** (1.32)	8.20 *** (1.92)	8.08 *** (2.38)
Log likelihood	–169.91	–167.95	–166.85
No. of observations	78	78	78

Table 3. Tobit regressions explaining the investment of rational-KMM-coherent subjects
Note: Standard errors in parentheses, * $p < 0.1$, **$p < 0.05$, *** $p < 0.01$

[29] As the left panel of Figure 4 shows, none of the rational-KMM-coherent subjects chose $a = 0$ and only 15/78 chose $a = 10$. Therefore, we also run OLS regressions with the same three specifications of Table 3, and found similar results. As further robustness check, we also run Tobit regressions with clustered errors at the session level (25 subjects per experimental session). Also in this case, results are similar to those presented in Table 3. Results of all these regressions are available upon request.

Table 3 shows that the only regressor explaining a subject's demand for annuities in period 1 is his/her attitude toward the ambiguous probability of being active ("alive") in period 2. In particular, ambiguity aversion elicited in phase A of the experiment significantly reduces the demand for annuities in phase B. Furthermore, the coefficient of the coherent-ambiguity aversion dummy is always significant at the 1% level in each of the three model specifications, thus providing robustness to this result: ambiguity aversion reduces the demand for annuities with or without controlling for the subject's warm-glow motivations and idiosyncratic features. A similar result is obtained if considering as regressor, rather than a dummy for ambiguity aversion, an ordered variable for subject's ambiguity attitude (–1 for aversion, 0 for neutrality, +1 for proneness).

Note that, although the coefficients of almost all charity-related measures of warm glow have the predicted (negative) sign in Model III, none of them is significant in either Model I or Model III. We have tried several other specifications with charity-related and perceived altruism variables as unique regressors (with or without controls for individual characteristics) and found none of them in which any of their coefficients is significant.

Finally, in Online Appendix C we provide two robustness checks of the regression analysis of Table 3. First, the modal choice 5 in the investment in the annuity (21/78 subjects) suggests strong heuristics at play. This might have led us to overestimate the fraction of subjects appearing as rational-KMM-coherent, since for some of them their decisions might be fundamentally based on bounded rationality. We replicate the regression models of Table 3 for H.1 by excluding these subjects and we find no difference (see Table C.3). Second, in Tables C.4 and C.5 we replicate the regression models of Table 3 for H1 by considering all the 100 subjects in the sample. In particular, in Table C.4 the main regressor is the value-ambiguity attitude elicited in tasks 1-2 of phase A, while in Table C.5 we rely on the choice-ambiguity attitude elicited in tasks 3-4 of phase A. We find that the coefficient of ambiguity aversion is the only significant coefficient in both regression analysis, with the predicted negative impact on the demand for annuities (at the 1% level for value ambiguity, and at the 5% level for choice ambiguity). Risk aversion is significant, at the 10% level, and only in Table C.4. A positive impact of age, again significant only at the 10% level, is detected in Table C.5. All this leads us to conclude that **H1 is verified**.

We conclude this section with the test of H2, that relies on the data reported in Figure 5. The figure focuses on the subjects' wealth allocation if active in period 2, disentangled by their ambiguity attitude. In particular, the left panel reports the average voluntary donation as absolute amount of wealth (x), while the right panel reports the same average as share of wealth $x/(10 + a)$. Figure 5 only focuses on the rational-KMM-coherent subjects. Figure C.1 in Online Appendix C provides a robustness check by considering all subjects in the experiment. In particular, for coherent ambiguity, we include the 17 unclassified subjects of Figure 1 in the category of coherent-ambiguity neutral.

Although Figure 5 does not report the average amount kept by the subject if active in period 2, namely $(10 + a - x)$, it is easy to guess it by looking at the right panel and measuring the complementary share $(10 + a - x)/(10 + a)$. The latter represents the portion of total wealth if active that the subject would keep for him/herself from phase B. For example, if disentangling by coherent ambiguity (last three bars of each panel), the average shares $(10 + a - x)/(10 + a)$ in the left panel are 81% for ambiguity-averse, 75%

for ambiguity-neutral, and 79% for ambiguity-loving subjects. The average amounts are, respectively, €12.3, €12.4, and €14.1. This picture is in line with the previous test of H1, showing that in period 1 ambiguity-averse subjects have invested less in the annuity.

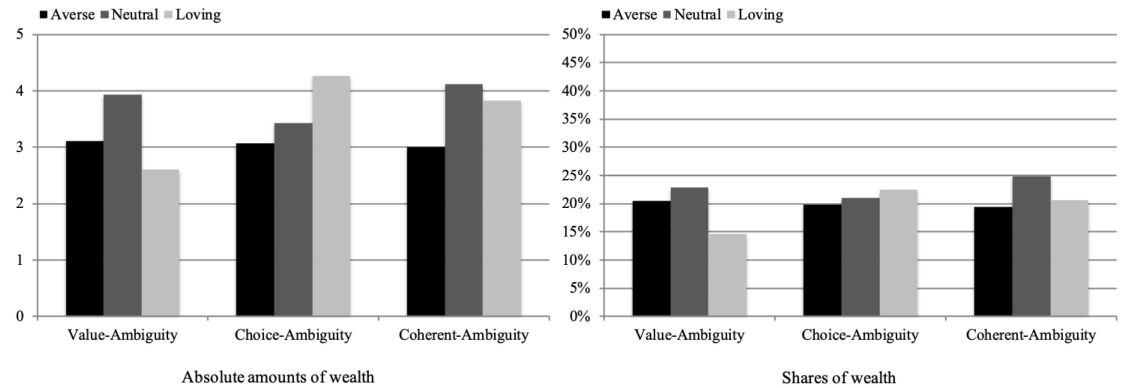

Figure 5.Voluntary donation as absolute amount of wealth (left panel) and as share of wealth (right panel) if active in period 2, by ambiguity attitude, rational-KMM-coherent subjects.

For each dimension of ambiguity attitude (value, choice, or coherent) and each sign (aversion, neutrality and proneness) given the dimension, the average share of total wealth voluntary donated to the chosen charity is between 15% and 25% in Figure 5 (it is between 19% and 29% in Figure C.1).[30] Therefore, no significant difference is essentially found across different ambiguity attitudes if considering value-ambiguity (Kruskal-Wallis test, *p-value* = 0.251), choice-ambiguity (*p-value* = 0.492) or coherent-ambiguity (*p-value* = 0.308). Pairwise comparisons of the mean values among ambiguity attitudes through *t*-tests confirm this result for ambiguity-averse subjects (smallest *p-value* = 0.147, found in the comparison between coherent-ambiguity averse and neutral subjects). The robustness check in Figure C.1 confirms that the only significant difference is found in the comparison between coherent-ambiguity averse and neutral subjects. As for ambiguity-loving subjects, we find only one significant difference, namely in the comparison between value-ambiguity loving and neutral subjects (*p-value* = 0.058). However, this difference is far from being significant if we replicate the test by considering all the 100 subjects in Figure C.1 (*p-value* = 0.653). By construction, the same results are found if focusing on the complementary share of total wealth, the one that the subject keeps for him/herself. Thus, we can state that **H2 is verified for the shares of wealth, for both donation and consumption**.

As for the absolute amounts of wealth, recall that H2 relies on the auxiliary assumption H0.ii (see Section 2), and that the latter works only if considering subjects with positive warm glow (see Table 2). Therefore, we restrict the attention to subjects with $x > 0$ if active in period 2. As for ambiguity-loving subjects, we find weak support in the analysis of the donation. In fact, the only significant difference is found by comparing

[30]The fact that the subjects' mean (median) voluntary donation to the charity is only 23% (21%) of the wealth if active in period 2, with 15/100 of subjects donating nothing, indirectly confirms that experimental demand effects on donation, if any, were not so strong. This result is also in line with the final remark subjects had in the experimental instructions before choosing the charity: "Entering the name of a charity does not require you to make it a donation in Phase B".

choice-ambiguity-loving subjects to choice-ambiguity-neutral and choice-ambiguity-averse subjects considered together (t-test, *p-value* = 0.086). However, the positive rank correlation is not significant (Spearman's *rho* = 0.17, *p-value* = 0.189). The robustness check of Figure C.1 confirms the same picture, with a significant difference (*p-value* = 0.047), and a non-significant positive correlation (Spearman's *rho* = 0.14, *p-value* = 0.21). We find instead strong support in the analysis of the consumption. Both value-ambiguity-loving and coherent-ambiguity-loving subjects keep significantly more for themselves compared to the other subjects (respectively, *p-value* = 0.032 and *p-value* = 0.002), with correlation analysis confirming this result (respectively, *rho* = 0.27, *p-value* = 0.033; *rho* = 0.38, *p-value* = 0.002). The robustness check of Figure C.1 confirms the same picture, with the same levels of significance.

As for ambiguity-averse subjects, we find equal support for both the amount donated and the amount they keep for themselves. As for the donation, compared to coherent-ambiguity-neutral and coherent-ambiguity-loving subjects considered together, coherent-ambiguity-averse subjects donate significantly less (t-test, *p-value* = 0.072). This is confirmed by rank correlation analysis (Spearman's *rho* = –0.22, *p-value* = 0.086). Furthermore, the robustness check of Figure C.1 improves the significance of this difference (t-test, *p-value* = 0.037) and of the negative correlation between ambiguity aversion and amount donated (Spearman's *rho* = –0.22, *p-value* = 0.044). As for the consumption, compared to value-ambiguity-neutral and value-ambiguity-loving subjects considered together, value-ambiguity-averse subjects keep for themselves significantly less (t-test, *p-value* = 0.006). This is confirmed by rank correlation analysis (Spearman's *rho* = –0.28, *p-value* = 0.023). Furthermore, we essentially find the same results if we consider the whole sample in Figure C.1 (t-test, *p-value* = 0.007; Spearman's *rho* = –0.23, *p-value* = 0.037).

With this, we can state that, **as for the amounts of wealth, H2 is verified for the consumption; it is verified for the donation only for ambiguity-averse subjects**.

5 Concluding remarks

Our study introduces a novel experimental design able to detect individuals' smooth ambiguity attitudes and relate them to life self-insurance decision problems. The experimental results support the intuition that ambiguity aversion may be a relevant motivation for the empirically observed under-annuitization puzzle when facing investment decisions where the (unknown) probability of being alive tomorrow is involved.

In fact, provided that annuities return is sufficiently larger than bonds return, and notably when—as in our experiment—it is fair, the optimal share of annuities in the portfolio should be positive. However, if the investor had a preference for known rather than unknown survival probabilities, he/she would find this financial instrument not so attractive. Thus, for a given level of uncertainty, an ambiguity-averse individual would invest less in annuities than an ambiguity-neutral one. This would ultimately reduce, upon survival, both his/her consumption and his/her bequest to the next generation, given that both should be increasing in the investment in annuities. Our experimental results confirm both these intuitions, by measuring ambiguity aversion within a KMM framework and employing donations toward a pre-selected charity as experimental proxies of warm-glow giving toward a related “next generation”.

There is a growing experimental literature on the behavioral determinants of the demand for insurance (see, *e.g.*, Corcos *et al.* 2017, and references therein), and on the impact of ambiguity aversion on insurance decisions (see, *e.g.*, Di Mauro & Maffioletti 1996, and Cabantous 2007). However, still few experimental studies have focused on annuities as an insurance instrument. Among relevant exceptions, the potential impact of recent stock returns on annuitization decisions was tested in an experimental setting by Agnew *et al.* (2015), confirming the impact of recent market performance and attributing it to excessive extrapolation. Earlier experiments (Agnew *et al.* 2008) have focused on the effects of priming and framing on the demand for annuities. Experiments were also used to investigate the impact of changes in the structure of annuity products with predetermined default choices (Gazzale *et al.* 2012) and how the decision to retire could be affected by the offer of annuities in the market (Fatas *et al.* 2007).

More recently, Hurwitz *et al.* (2019) have investigated in a laboratory experiment the introduction and repeal of mandatory minimum annuity laws, and found that the demand for annuities was sensitive to the mandatory-minimum mechanism and consistent with anchoring to the signal reflected in the requirement. Their control treatment, *i.e.*, without mandatory minimum annuity, is comparable to our experimental setting. As in our design, building on Yaari (1965), the decision in the first of the two-period computerized task is the distribution of money between an annuity and a lump sum, with ambiguous survival probabilities. Differently from ours, in the second period subjects have no bequest decision to take, hence warm-glow giving is not an issue. Furthermore, contrarily to our neutral setting, they distribute framed instructions representing a scenario in which subjects learn they are at the stage of life just before retirement and have saved a given amount of money. Again contrarily to our “investment” frame of demand for annuities, they simulate a real-life situation in which retirees perceive annuities as a “consumption” tool (see Brown *et al.*, 2008). Finally, and more importantly, their experiment is not theory-driven: no theoretical framework is provided, and ambiguity attitudes are not elicited.

Therefore, to the best of our knowledge, ours is the first experimental test of the under-annuitization puzzle employing at the same time individual (ambiguity attitude) and social (warm-glow giving) preferences. In this regard, the main finding of our study is that the under-annuitization puzzle is much more related to ambiguous survival probabilities than to a bequest motive. Recent empirical results reinforce our argument that the problem of under-annuitization is not so much related to the perception of the risk of death but rather to the aversion to the ambiguity associated with that risk. Boyer *et al.* (2019) have run a stated-preference survey to estimate the demand for individual annuities in Canada. They find that if relying on objective survival probabilities (*i.e.*, those displayed in Life Tables), then the pricing of the annuity turns out to be “unfair” according to the respondents’ stated preferences. On the other hand, if they use the subjective survival probabilities (those reported by the respondents), then the pricing of annuities turns out to be “fair”. Therefore, they conclude that it is not the misperception on the life span that can explain the low demand for annuity.

The main advantages and limitations of this paper lie in the adopted methodology. In fact, we rely on an economic experiment based on a stylized setting where the impact of smooth ambiguity aversion to uncertain survival probabilities on the demand for annuities is studied in a simple 'portfolio choice - charity donation' two-period decision problem. On the one side, this has allowed us to study the under-annuitization puzzle in a setting that is not contaminated with other real-life financial instruments such as life insurance, which could complicate the study of annuities as known from prior literature. On the other side, the laboratory setting can suffer of some limitations due to the simplification of the reality. For example, the time dimension is absent, since the experiment is based on a two-period problem in which the "period" corresponds to the decision period and not to a time period. And in the real world the under-annuitization puzzle should be strongly related to the interaction between delay and ambiguity (see the survey in Benartzi *et al.* 2011). Another limitation of our setting is that annuities do not have an upfront cost: investments are made and the only risk is whether the decision maker can live to enjoy it. But in the real world people must sacrifice some current consumption to buy an annuity. All this of course reduces the external validity of our results. However, this methodology offers the possibility to observe behaviors and variables that otherwise could not be observed in the field (*e.g.*, warm-glow donations to the "next generation). Furthermore, it allows to set the same objective parameters of the annuity-bequest decision problem (*e.g.*, initial endowment, bond and annuity returns) for all the subjects in the sample, thereby analyzing their behavior in the same controlled decision environment. Both these features makes it possible to elaborate clear-cut predictions about the relation between ambiguity aversion and investment in annuities by relying on decision-theoretic tools within a specific framework, namely KMM, and thereby focusing on decision makers who disclose a behavior coherent with the axiomatization of this model.

Several interesting extensions of our theory-driven experimental study are possible. We discuss more in depth three of them. First, as anticipated above when discussing the limitations of our study, the decision problem of phase B could have tried to incorporate consumption in period 1, with payments made to the experimental subjects at that time. This is obviously a more complex set-up from a theoretical point of view. In Online Appendix A we add an extension of the model of Section 2 (see Extension 1) with consumption of the endowment allowed in period 1. We show that, for an ambiguity-neutral subject, introducing consumption also in period 1 leads to a lower consumption in period 2 and to a lower demand for annuities in period 1. The intuition would lean towards stating that this holds independently of the ambiguity attitude (see d'Albis & Thibault 2012). However, the size of the decrease in the demand for annuities should depend on the ambiguity attitude. The experimental test of this extended decision problem within a KMM framework would provide support the external validity of our study.

Second, and again starting from a limitation of our study, an extension of our laboratory experiment testing the interplay between delay and ambiguity on under-annuitization would be relevant. On the one side, recent theoretical studies show that under hyperbolic discounting annuities are rarely purchased (Tang *et al. 2018*), although empirical evidence on the impact of personal discount rates on demand for annuities is rare, probably due to the difficulty of obtaining reliable estimates of personal discount rates in the field of annuitization (as an exception, see Warner & Pleeter 2001). On the other side, experimental studies on the sources of ambiguity have shown a similarity in behavior between the risk and delay versions of the Ellsberg paradox (see, *e.g.*, Weber & Tan 2012), thereby suggesting that ambiguity aversion increases in the ambiguous delay.

Third, in real life also bonds are ambiguous. This ambiguity should then directly transmit to the annuities, whose return also depends on the bonds' interest rate. Thus, this should have little effect on the relative demand for annuities. What we do in our study is to neutralize this common effect in order to focus on a specific source of uncertainty, namely on the risk of death. More in general, ambiguity-averse investors might prefer financial products that combine an annuity and a life insurance, thereby hedging across different ambiguous states of the world. This would challenge the standard distinction between "survival cover" and "death cover" insurances in financial markets. Therefore, our experimental setting could be extended by introducing a third possible investment, intermediate between bonds and annuities, which works as death insurance: in case of death, the relatives receive a higher amount of money the higher the investment in this financial product. Such product may fully protect against all state-dependent contingencies. We leave to future research the experimental test of the effectiveness of these mixed instruments of self-protection against ambiguous survival probabilities. Such a study might help private firms and public authorities to reshape current financial instruments of self-insurance for decision makers uncertain about the probability of being alive tomorrow.

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An Experimental Test of the Under-Annuitization Puzzle with Smooth Ambiguity and Charitable Giving

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Online Appendix A

In this Online Appendix we prove the theoretical results of Section 2 and some extensions of them in the general case of a random variable (ambiguous survival probability) $\widetilde{p}$ with mean survival probability $E(\widetilde{p}) = 1/2$.

Proof of Proposition 1

Using equation (7), let us define $F(a^\star_\phi, x^\star_\phi) = -g'[10 + a^\star_\phi - x^\star_\phi] + h'[x^\star_\phi] = 0$. Since the trade-off between consumption $10 + a^\star_\phi - x^\star_\phi$ and bequest $x^\star_\phi$ if alive is not affected by the survival probability, it does not depend on the ambiguity attitude of the DM. As $F'_1(a^\star_\phi, x^\star_\phi) = -g''[10 + a^\star_\phi - x^\star_\phi] > 0$ and $F'_2(a^\star_\phi, x^\star_\phi) = g''[10 + a^\star_\phi - x^\star_\phi] + h''[x^\star_\phi] < 0$, there exists a continuous and differentiable function f such that $x^\star_\phi = f(a^\star_\phi)$. As $f'(a^\star_\phi) = -F'_1(a^\star_\phi, x^\star_\phi)/F'_2(a^\star_\phi, x^\star_\phi) = g''[10 + a^\star_\phi - x^\star_\phi]/\{g''[10 + a^\star_\phi - x^\star_\phi] + h''[x^\star_\phi]\} \in (0, 1)$, $x^\star_\phi = f(a^\star_\phi)$ and $c^\star_\phi = 10 + a^\star_\phi - f(a^\star_\phi)$ increase with $a^\star_\phi$. $\square$

Proof of Proposition 2

When ϕ is linear, *i.e.*, $\phi'' = 0$, the utility function in Eq. (4) rewrites $\mathcal{U}(a, x, 1/2)$, which is linear with respect to the mean survival probability, $p = 1/2$. We may interpret 1/2 as a survival probability subjectively evaluated by the DM and thus the problem, denoted $\mathcal{P}_0$, is the one of a subjective expected utility maximizer:

$$\begin{array}{ll} \max\limits_{a,x} & \frac{1}{2}\{g[10+a-x]\}+\frac{1}{2}\{h[x]+h[10-a]\} \\ s.t. & 10+a-x\geq 0,\ x\geq 0 \text{ and } a\leq 10. \end{array}$$

Merging the two FOCs, we obtain that the optimal demand for annuities $a_0^\star$ is such that: $h'[10-a_0^\star] = h'[f(a_0^\star)]$. Then, $a_0^\star = 10 - f(a_0^\star) > 0$, $x_0^\star = f(a_0^\star)$ and $c_0^\star = 2a_0^\star$.

We now consider the problem $\mathcal{P}_\phi$ in Eq. (5) and denote by $(a_\phi^\star, x_\phi^\star)$ its solution, which is the solution of the system of equations (6) and (7). Let us define the random variables $\Delta(a,\widetilde{p}) = \widetilde{p}(g[10+a-f(a)]+h[f(a)])+(1-\widetilde{p})h[10-a]$ and $\Omega(a,\widetilde{p}) = \widetilde{p}g'[10+a-f(a)] - (1-\widetilde{p})g'[10-a]$, where $x = f(a)$ is derived from equation (7) (see Proof of Proposition 1).

Then, the system of equations (6) and (7) rewrites as a single equation in a:

$$\eta_\phi(a) = E\Big(\phi'(\Delta(a,\widetilde{p}))\times\Omega(a,\widetilde{p})\Big) = 0.$$

As $f(a)$ is such that $g'[10+a-f(a)] = h'[f(a)]$ we have $\Delta'_a(a,\widetilde{p}) = \Omega(a,\widetilde{p})$. Then

$$\eta'_\phi(a) = E\Big(\phi'(\Delta(a,\widetilde{p}))\times\Omega'_a(a,\widetilde{p}) + \phi''(\Delta(a,\widetilde{p}))\times\Omega^2(a,\widetilde{p})\Big).$$

As $\Omega'_a(a,\widetilde{p}) = \widetilde{p}(1-f(a))g''[10+a-f(a)] + (1-\widetilde{p})h''[10-a] < 0$, $\eta'_\phi(a) < 0$ when ϕ is not too convex. We restrict our attention to the cases where ϕ is concave, linear and not too convex to be sure that the problem $\mathcal{P}_\phi$ is a concave problem (*i.e.*, the concavity of the SOCs – linked to the sign of $\eta'_\phi(a)$ – is satisfied).

Since $E\Big(\Omega(a_0^\star,\widetilde{p})\Big) = 0$ (see the FOCs of $\mathcal{P}_0$) in Eqs. (6-7), we have $\eta_\phi(a_0^\star) = E\Big(\phi'(\Delta(a_0^\star,\widetilde{p}))\times\Omega(a_0^\star,\widetilde{p})\Big) = Cov\Big(\phi'(\Delta(a_0^\star,\widetilde{p})),\Omega(a_0^\star,\widetilde{p})\Big)$. Consequently, $\eta_\phi(a_0^\star) < 0$ when ϕ is concave and $\eta_\phi(a_0^\star) > 0$ when ϕ is convex. Consequently, as $\eta'_\phi(a) < 0$, the (unique) real root $a_\phi^\star$ of η_ϕ is such that $a_\phi^\star < a_0^\star$ when ϕ is concave and $a_\phi^\star > a_0^\star$ when ϕ is convex. □

Extension 1: For an ambiguity-neutral DM, the demand for annuities would be lower (*ceteris paribus*) if consumption in period 1 were evaluated in the utility function.

Suppose that in period 1 the DM is also given the possibility of consuming his/her endowment. In the experimental setting, this would mean allowing the subject to be paid in period 1 by the experimenter (part of) his/her initial endowment of €10 of phase B. This payment would be independent of being or not being active in period 2 of phase B.

Introducing in the model of Section 2 consumption in period 1, namely c_1, the budget constraint in Eq. (1) extends to $c_1 = 10 - a - b$ and $c_2 = 2a + b - x$, with non-negativity constraints in Eq. (2) holding, extended as $c_1 \geq 0$ and $c_2 \geq 0$.

Suppose that the subject evaluates c_1 according to a positive and increasing utility function $m(\cdot)$. Also suppose that the DM is ambiguity-neutral, *i.e.*, ϕ is linear. Thus, as for the benchmark case in Proof of Proposition 1, we may interpret 1/2 as a survival probability subjectively evaluated by the DM. Thus, the problem of maximization of the lifetime Expected Utility in period 1 in Eq. (3) becomes:

$$\begin{array}{ll}\max\limits_{a,b,x} & m(10-a-b)+\frac{1}{2}\{g[2a+b-x]\}+\frac{1}{2}\{h[b]+h[x]\} \\ s.t. & 10-a-b\geq 0,\ 2a+b-x\geq 0,\ x\geq 0 \text{ and } a\leq 10.\end{array}$$

Merging the three FOCs for a, b and x, we obtain $2h'(b^\star)=h'(x^\star)$ and then, $x^\star < b^\star$. Consequently, using the budgetary constraint, one obtains $c_2^\star > 2a^\star$. Obviously, introducing consumption in period 1 reduces consumption in period 2. Then, $c_2^\star \leq c_0^\star$ where $c_0^\star = 2a_0^\star$ is defined in Proof of Proposition 2. As $2a_0^\star \geq c_2^\star > 2a^\star$, we have $a_0^\star > a^\star$, where $a_0^\star$ is defined in Proof of Proposition 2.

Extension 2: For an ambiguity-neutral DM, the demand for annuities increases in the subject's wealth from phase A.

Let k be the subject's earnings from phase A of the experiment. This wealth can be used by the subject (*i.e.*, be paid by the experimenter) independently from the fact that he/she is active or not active in period 2 of phase B.

We assume that if the subject is active in period 2, hence receving positive earnings also from phase B, wealth k sums up to these earnings within function $g(\cdot)$. If instead the subject is not active in period 2, hence getting no private earning from phase B, he/she evaluates k according to a positive and increasing utility function $\varepsilon(\cdot)$. Also assume that the DM is ambiguity-neutral, *i.e.*, ϕ is linear. Thus, as for the benchmark case in Proof of Proposition 1, we may interpret 1/2 as a survival probability subjectively evaluated by the DM. Thus, the problem of maximization of the lifetime Expected Utility in period 1 in Eq. (3) becomes:

$$\begin{array}{ll}\max\limits_{a,x} & \frac{1}{2}\{g[10+a+k-x]+h[x]\}+\frac{1}{2}\{\varepsilon[k]+h[10-a]\} \\ s.t. & 10+a+k-x\geq 0,\ x\geq 0 \text{ and } a\leq 10.\end{array}$$

Note that if $k=0$ this maximization problem reduces to the one at the beginning of the Proof of Proposition 2, and $a_0^\star = 10-f(a_0^\star)$. Merging the two FOCs we obtain $h'(10-a_k^\star) = h'(x_k^\star)$ and then, $a_k^\star = 10 - x_k^\star$ where $F(a_k^\star, x_k^\star, k) = -g'[10+a_k^\star+k-x_k^\star]+h'[x_k^\star]=0$. Importantly, $F(a_0^\star, x_0^\star, 0)$ was function F introduced in Proof of Proposition 1. Thus we have $F_1' > 0$ and $F_2' < 0$. Since here $F_3' = -g'(.)$ is negative, we have $x_k^\star = f(a_k^\star, k)$ with $f_2' < 0$. Then $x_k^\star = f(a_k^\star, k) < x_0^\star = f(a_0^\star, 0)$. Since $a_k^\star = 10 - x_k^\star$ and $a_0^\star = 10 - x_0^\star$, we have $a_k^\star > a_0^\star$.

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Online Appendix B

Experimental Instructions

[Translated from French]

Welcome to the Laboratory of Experimental Economics of Strasbourg.
You will be participating in an experiment on decision-making. All participants in the experiment have the same instructions.
If you follow the instructions carefully, your decisions can let you earn money.
The amount of money that you will earn will depend partially on your decisions and partially on random draws. It will not depend on the decisions of the other participants in the experiment.
The amount of money that you will earn will be paid out in cash at the end of the experiment.
Once you have read all the instructions, please ask any questions you may have.

General Instructions

This experiment consists of two phases, A and B.
The instructions for Phase A will be handed out shortly.
The instructions for Phase B will be handed out after the end of Phase A.
You can earn money in each phase. The total amount of money you will earn during the experiment will be the sum of your earnings in the two phases.
You will know how much you have earned in Phase A only at the end of the experiment.
At the end of the experiment, we will call you in order for you to privately receive your earnings in the two phases in cash.

Instructions for PHASE A

Phase A is made by **four tasks** where you have to make decisions about a series of lotteries.
Each lottery is associated to an urn containing yellow and blue balls. For each task, the urn is the same for all participants in the experiment.

Before the beginning of Phase A, the computer will ask you to choose between colors yellow and blue. This will be your "**winning color**" for each of the urns of Phase A.

Only **one out of the four tasks** will be used to determine your earnings in Phase A. You will know which task will be used to determine your earnings only at the end of the experiment, after Phase B.
At the end of the experiment, one of the participants will be asked to make a random draw from an envelope containing four numbers. The drawn number (1, 2, 3, or 4) will indicate the number of the task used to determine earnings in Phase A for all participants. Then, only this task will be performed.
In particular, the computer will randomly select a ball from the urn associated to the randomly drawn task. The color of the randomly selected ball will be used to determine the earnings of all participants.

Below you have the instructions for Task 1.

Instructions of each new task will be handed out only after the end of the previous one.

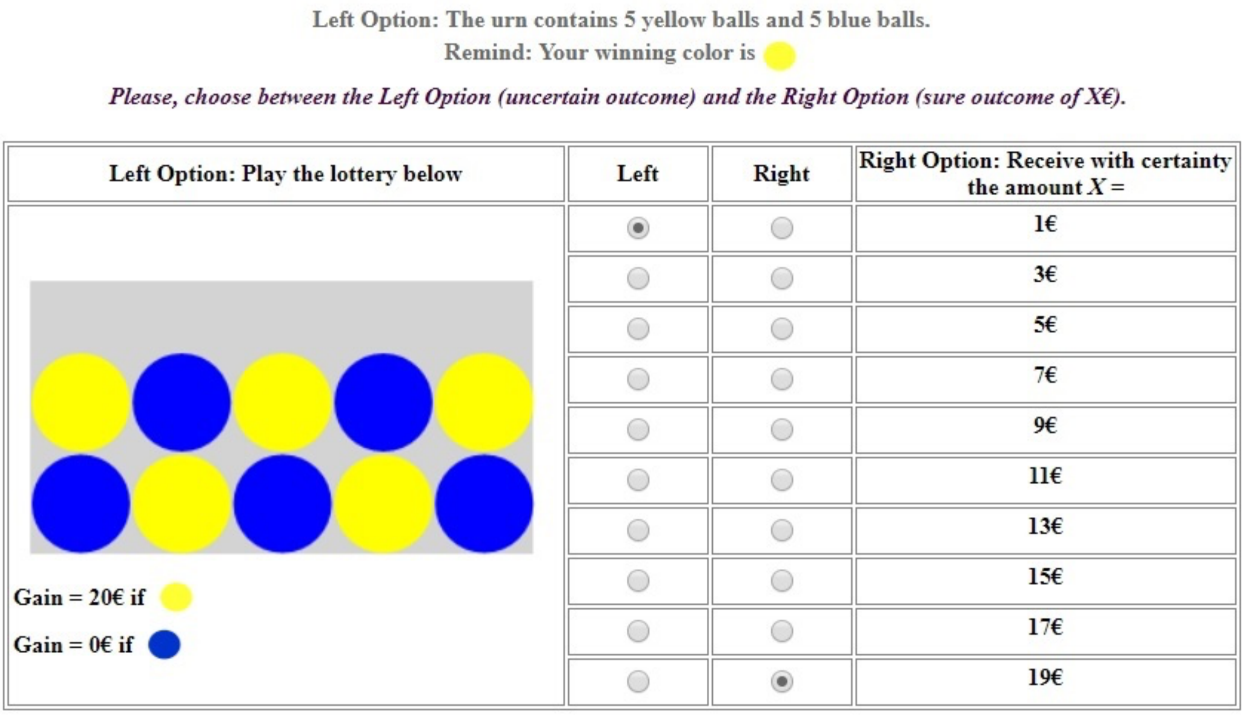
- **<u>Instructions for TASK 1</u>**

For each line of Screen 1, you have to choose between two options: option “Left” and option “Right.” Earnings are expressed in euros.

Options:

– Option Left is a lottery. The computer will randomly select a ball from an urn that contains 5 yellow balls and 5 blue balls (see Screen 1). If the drawn ball is of the same color as your winning color, then you will get 20€; otherwise you will get 0€.

– Option Right will give you a sure amount X within a range from 1€ (first line) to 19€ (last line).



Screen 1 (Example for a participant who has chosen “yellow” as winning color)

Remark:
You cannot make inconsistent decisions. If you select option Left for a given amount X, you are automatically assigned by the computer option Left also for all amounts *lower* than X. If you select option Right for a given amount X, you are automatically assigned by the computer option Right also for all amounts *higher* than X.

Payment:
If at the end of the experiment Task 1 will be randomly drawn to determine your earnings for Phase A, the computer will randomly select an amount X among the ten amounts in Screen 1 (the probability for an amount X to be chosen is, for each amount, 1/10).
For this amount X, same for all participants:

– If you have chosen option Left during the experiment, the computer will draw a ball from the urn with 5 yellow and 5 blue balls of Screen 1. If the ball is of the same color as your winning color, you will earn 20€; otherwise, you will earn 0€.

– If you have chosen option Right during the experiment, you will earn X€, corresponding to the randomly selected amount.

- **Instructions for TASK 2**

For each line of Screen 2, you have to choose between two options: option “Left” and option “Right.” Earnings are expressed in euros.

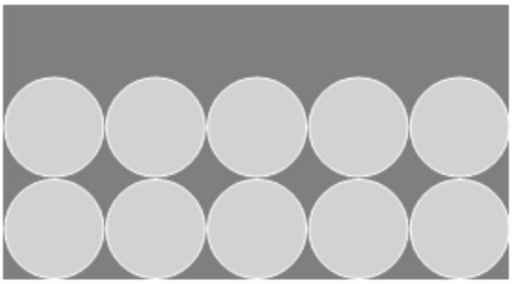
Options:

- Option Left is a lottery. The only difference with respect to Task 1 is that the composition in terms of yellow and blue balls of the 10-ball urn used for option “Left” in Screen 2 is unknown. The urn may contain from 0 to 10 yellow balls and from 0 to 10 blue balls. The composition of the urn, same for all participants, has been determined before the experiment by randomly drawing one of the eleven possible compositions of balls (0 yellow – 10 blue, 1 yellow – 9 blue, …, 9 yellow – 1 blue, 10 yellow – 0 blue) . The computer will randomly select a ball from this urn. If the drawn ball is of the same color as your winning color, then you will get 20€; otherwise you will get 0€.
- Option Right will give you a sure amount X within a range from 1€ (first line) to 19€ (last line).

Left Option: The urn contains 10 balls, of which the number of yellow and blue balls is unknown.

Remind: Your winning color is ●

Please, choose between the Left Option (uncertain outcome) and the Right Option (sure outcome of X€).

Left Option: Play the lottery below	Left	Right	Right Option: Receive with certainty the amount *X* =
	◉	○	1€
	○	○	3€
	○	○	5€
	○	○	7€
	○	○	9€
	○	○	11€
	○	○	13€
Gain = 20€ if ● (yellow)	○	○	15€
Gain = 0€ if ● (blue)	○	○	17€
	○	◉	19€

Screen 2 (Example for a participant who has chosen “yellow” as winning color)

Remark:
You cannot make inconsistent decisions. If you select option Left for a given amount X, you are automatically assigned by the computer option Left also for all amounts *lower* than X. If you select option Right for a given amount X, you are automatically assigned by the computer option Right also for all amounts *higher* than X.

Payment:
If at the end of the experiment Task 2 will be randomly drawn to determine your earnings for Phase A, the computer will randomly select an amount X among the ten amounts in Screen 2 (the probability for an amount X to be chosen is, for each amount, 1/10).
For this amount X, same for all participants:

- If you have chosen option Left during the experiment, the computer will draw a ball from the urn with unknown composition of Screen 2. If the ball is of the same color as your winning color, you will earn 20€; otherwise, you will win 0€.
- If you have chosen option Right during the experiment, you will earn X€, corresponding to the randomly selected amount.

- <u>**Instructions for TASK 3**</u>

You have to choose one of the ten lines of Screen 3, denoted by L1, L2, L3, L4, L5, L6, L7, L8, L9, and L10. Each line indicates a different lottery. Earnings are expressed in euros.

Each lottery consists of a random draw of a ball from an urn. The urn is the same for the ten lines of Screen 3, containing 5 yellow balls and 5 blue balls.

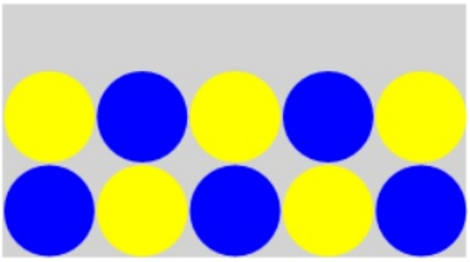
If the ball drawn is of the same color as your winning color, then you will receive the largest amount among the two that you have chosen, otherwise you will receive the smallest one.

Options:
The ten lines (lotteries) differ by the two amounts you can earn:

– if you choose lottery L1 and the ball drawn is of the same color as your winning color, you will receive 11€; otherwise, you will receive 9€;
– if you choose lottery L2 and the ball drawn is of the same color as your winning color, you will receive 12€; otherwise, you will receive 8€;
– …
– if you choose lottery L10 and the ball drawn is of the same color as your winning color, you will receive 20€; otherwise, you will receive 0€.

The urn contains 5 yellow balls and 5 blue balls.
Remind: Your winning color is

Please, choose one of the 10 lines below.

You play the lottery below	Lines	Gain if	Gain if	Your choice
	L1	11€	9€	
	L2	12€	8€	
	L3	13€	7€	
	L4	14€	6€	
	L5	15€	5€	
	L6	16€	4€	
	L7	17€	3€	
	L8	18€	2€	
	L9	19€	1€	
	L10	20€	0€	

Screen 3 (Example for a participant who has chosen "yellow" as winning color)

Payment:
If at the end of the experiment Task 3 will be randomly drawn to determine your earnings for Phase A, the computer will randomly select one ball from the urn containing 5 yellow balls and 5 blue balls. Then, the computer will check which line (lottery) you have chosen in Screen 3:

– if the drawn ball is of the same color as your winning color, you will earn the largest of the two lottery amounts that you have chosen in Screen 3;
– if the drawn ball is of the other color, you will earn the smallest of the two lottery amounts that you have chosen in Screen 3.

- **<u>Instructions for TASK 4</u>**

You have to choose one of the ten lines of Screen 4, denoted by L1, L2, L3, L4, L5, L6, L7, L8, L9, and L10. Each line indicates a different lottery. Earnings are expressed in euros.

Each lottery consists of a random draw of a ball from an urn. The urn is the same for the ten lines of Screen 4. The only difference with respect to Task 3 is that the composition in terms of yellow and blue balls of the 10-ball urn is unknown (see Screen 4 below). The urn may contain from 0 to 10 yellow balls and from 0 to 10 blue balls. The composition of the urn, same for all participants, has been determined before the experiment by randomly drawing one of the eleven possible compositions of balls (0 yellow – 10 blue, 1 yellow – 9 blue, …, 9 yellow – 1 blue, 10 yellow – 0 blue). In particular, two independent random draws has been made to determine the composition of the 10-ball urns of Task 2 and of Task 4.

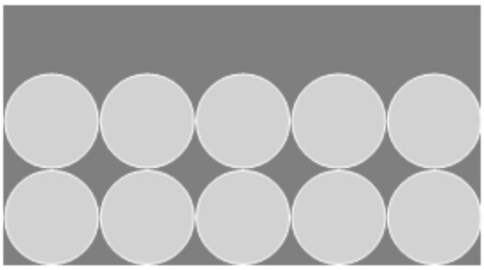
If the ball drawn is of the same color as your winning color, then you will receive the largest amount among the two that you have chosen, otherwise you will receive the smallest one.

Options:
The ten lines (lotteries) differ by the two amounts you can earn:
- if you choose lottery L1 and the ball drawn is of the same color as your winning color, you will receive 11€; otherwise, you will receive 9€;
- if you choose lottery L2 and the ball drawn is of the same color as your winning color, you will receive 12€; otherwise, you will receive 8€;
- …
- if you choose lottery L10 and the ball drawn is of the same color as your winning color, you will receive 20€; otherwise, you will receive 0€.

The urn contains 10 balls, of which the number of yellow and blue balls is unknown.

Remind: Your winning color is

Please, choose one of the 10 lines below.

You play the lottery below	Lines	Gain if	Gain if	Your choice
	L1	11€	9€	
	L2	12€	8€	
	L3	13€	7€	
	L4	14€	6€	
	L5	15€	5€	
	L6	16€	4€	
	L7	17€	3€	
	L8	18€	2€	
	L9	19€	1€	
	L10	20€	0€	

Screen 4 (Example for a participant who has chosen "yellow" as winning color)

Payment:
If at the end of the experiment Task 4 will be randomly drawn to determine your earnings for Phase A, the computer will randomly select one ball from the unknown urn of Screen 4.
Then, the computer will check which line (lottery) you have chosen in Screen 4:
- if the drawn ball is of the same color as your winning color, you will earn the largest of the two lottery amounts that you have chosen in Screen 4;
- if the drawn ball is of the other color, you will earn the smallest of the two lottery amounts that you have chosen in Screen 4.

Instructions for PHASE B

This phase consists of a game where you can earn money, that will be paid out in cash at the end of the experiment.

Before the beginning of the game, we will ask you to choose a **charity** to which you can, if you wish, donate some of the money you will earn in Phase B of the experiment.

A short questionnaire about the chosen charity and your charitable activities will follow.

Then, the game of Phase B will start.

Choice of the Charity

You should indicate a charity to which you can, if you wish, donate some of the money you will earn in Phase B of the experiment.

You are given 5 minutes to surf the web, find the website of the chosen charity, and copy-paste it on the screen of the experimental software.

We need you to indicate a charity which is endowed with an on-line donation system. In fact, immediately after having privately paid all subjects' earnings, the experimenter will go through the charity's website indicated by each subject at the beginning of Phase B, make the on-line donation and fill in the donation screen with the identity of the donor; the email confirmation of the electronic donation will be privately forwarded by the experimenter to the subject within 24 hours after the end of the experiment, so as to account for possible delays due to any charity's website problems.

Q1: Which is the name and website of the charity for which you will eventually make a donation using the earnings you will receive in the game of Phase B?

Name: ________________________________ Website: ________________________________

Remark: Entering the name of a charity does not require you to make it a donation in Phase B.

Q2: For how many years have you known this charity?

○ Less than 1 year ○ 1 year ○ 2 years ○ 3 years ○ 4 years ○ more than 4 years

Q.3: How many times have you already donated to this charity?

○ 0 times ○ 1 time ○ 2 times ○ 3 times ○ 4 times ○ more than 4 times

Q.4: Did you ever participate in the activities of this charity?

○ Yes ○ No

Q.5: Is any of your relatives or friends directly concerned by this charity?

○ Yes ○ No

Q.6: Would you say that most of the times people only care about themselves or they try to help others?

0 (Most of the time people only care about themselves)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10** (Most of the time people try to help others)
○	○	○	○	○	○	○	○	○	○	○

Q.7: Would you say that most of the times you only care about yourself or you try to help others?

0 (Most of the time you only care about yourself)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10** (Most of the time you try to help others)
○	○	○	○	○	○	○	○	○	○	○

GAME of Phase B

The game you will play in Phase B is a two-period investment-donation game.
Below we describe in detail the **investment choice** you will be asked to make in **period 1**, and the **donation choice** you will be asked to make in **period 2**.

- <u>**Period 1**</u> **[Investment choice]**

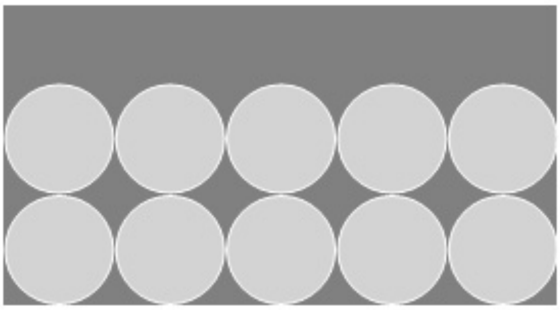
You will be given an initial endowment of 10€. You have to choose the amount of this endowment to invest in a project. Call this amount '**invested amount**': an integer number between 0€ and 10€. Call '**amount not invested**' the difference between your endowment and the invested amount.

In period 2, according to a random draw of a ball from an urn,

- you will get the sum of the **amount not invested** and of twice of the **invested amount**;
- you will lose the **invested amount**, **and** the **amount not invested** will be transferred to the charity that you have previously chosen.

- <u>**Period 2**</u> **[Donation choice]**

The computer will randomly draw a ball from a 10-ball urn with unknown composition in terms of yellow and blue balls (see Screen 5). Thus, it may contain from 0 to 10 yellow balls and from 0 to 10 blue balls. The composition of the urn, same for all participants, has been determined before the experiment by randomly drawing one of the eleven possible compositions of balls (0 yellow – 10 blue, 1 yellow – 9 blue, …, 9 yellow – 1 blue, 10 yellow – 0 blue). In particular, three independent random draws has been made to determine the composition of the 10-ball urns of Task 2 of Phase A (Screen 2), of Task 4 of Phase A (Screen 4), and of Phase B (Screen 5 below).



Screen 5 (Urn with unknown number of yellow and blue balls, used for Phase B)

The computer will compare the color of the randomly drawn ball, same for all subjects, with your '**winning color**,' that you have indicated at the beginning of the experiment. Two cases are possible:

- If the color of the drawn ball will be the same as your winning color,
  - you will get the sum of the **amount not invested** and of twice of the **invested amount**: call this sum your '**total gain**' in Phase B;
- If the color of the drawn ball will be different from your winning color,
  - you will lose the **invested amount**, **and** the **amount not invested** will be transferred to the charity that you have previously chosen.

Before knowing the color of the randomly drawn ball, you will be asked to indicate the **amount donated to the charity**. This is the portion of your total gain in Phase B that you would like to donate to the charity that you have previously chosen, in the event that the ball drawn is of the same color as your winning color. You can indicate any integer number between 0€ and your total gain.

Remark

Although you will take your donation choice before the computer's random draw of the ball, it will be effective in period 2 only if the ball drawn will be of the same color as your winning color.

- **<u>Payment</u>**

We now explain in more detail how your earnings in Phase B will be calculated according to:

- your investment choice in period 1;
- your donation to the charity in period 2;
- the color of the randomly drawn ball in period 2.

As anticipated above, two cases are possible, according to the color of the randomly drawn ball in period 2:

Case "drawn color same as your winning color":

- the invested amount is multiplied by 2 and made available to you for period 2;
- the amount not invested is made available to you for period 2;
- the charity's earnings in Phase B are equal to your donation choice (portion of your total gain in period 2 that you have decided to donate to the charity) at the end of the experiment;
- your earnings in Phase B are equal to the amount kept by yourself: your total gain (sum of the amount not invested and of twice of the invested amount) minus the donation to the charity.

Thus, in this case the charity's earnings (transferred to the charity at the end of the experiment) depend on both your investment choice in period 1 and on your donation choice in period 2.

Case "drawn color different from your winning color":

- the invested amount is lost;
- the amount not invested is transferred to the charity at the end of the experiment;
- the charity's earnings in Phase B are equal to your amount not invested in period 1 (initial endowment minus your invested amount in period 1);
- your earnings in Phase B are equal to 0.

Thus, in this case the charity's earnings (transferred to the charity at the end of the experiment) only depend on your investment choice in period 1. Your donation choice will not be applied in period 2.

- **<u>Example</u>**

Suppose that your invested amount in period 1 is 6€.
Therefore, your amount not invested is (10€ – 6€) = 4€.
If the ball drawn in period 2 will be of the same color as your winning color, your total gain in period 2 will be [4€ + (2 x 6€)] = 16€.
Suppose that in period 2 your donation choice is 3€.
Then, given your investment choice in period 1 and your donation choice in period 2,

- if the drawn ball will be of the same color as your winning color,
  - the charity's earnings will be 3€;
  - your earnings in Phase B will be (16€ – 3€) = 13€.
- if the drawn ball will be of the other color,
  - the charity's earnings will be 4€ (independent of your donation choice in period 2);
  - your earnings in Phase B will be 0€.

- **<u>Remark</u>**

Recall that, independently from the color of the drawn ball, the charity's earnings will be transferred on your behalf to your chosen charity by the experimenter immediately after the end of the experiment. You will receive the donation receipt by E-mail within 24 hours after the end of the experiment.

Control Questions

Before the game of Phase B begins, you will be asked to answer two sets of 4 control questions, aimed at stating your comprehension of the rules and possible earnings in the game.
If you make no mistake in the first set of 4 control questions, you will be allowed to skip the second set of control questions, and directly play the game.
If you make at least one mistake in the first set of 4 control questions, you will also be asked to answer the second set of control questions before playing the game.
You will be allowed to participate in the game independently from your answers to the control questions.

Set of Control Questions 1:

Suppose that you have chosen to invest **2€** in period 1, and to donate **5€** to the charity in period 2 in the event that the color of the randomly drawn ball will be the same as your winning color.

1.a) Assume that the color of the randomly drawn ball is **the same as your winning color**. Which will be **your earnings** in Phase B? __ €

1.b) Assume that the color of the randomly drawn ball is **the same as your winning color**. Which will be **the charity's earnings** in Phase B? __ €

1.c) Assume that the color of the randomly drawn ball is **different from your winning color**. Which will be **your earnings** in Phase B? __ €

1.d) Assume that the color of the randomly drawn ball is **different from your winning color**. Which will be **the charity's earnings** in Phase B? __ €

[*Shown only if the subject has made at least one mistake in the Set of Control Questions 1*]

Set of Control Questions 2:

Suppose that you have chosen to invest **8€** in period 1, and to donate **15€** to the charity in period 2 in the event that the color of the randomly drawn ball will be the same as your winning color.

2.a) Assume that the color of the randomly drawn ball is **the same as your winning color**. Which will be **your earnings** in Phase B? __ €

2.b) Assume that the color of the randomly drawn ball is **the same as your winning color**. Which will be **the charity's earnings** in Phase B? __ €

2.c) Assume that the color of the randomly drawn ball is **different from your winning color**. Which will be **your earnings** in Phase B? __ €

2.d) Assume that the color of the randomly drawn ball is **different from your winning color**. Which will be **the charity's earnings** in Phase B? __ €

[*Game of Phase B implemented*]

[*Final Questionnaire distributed: Questions about gender, age, year and field of study, income, and self-assessment of subjective discount rate*]

[*Random draw of a ball from the urn in Screen 5, in order to determine subjects' earnings in Phase B*]

[*Random selection of one of the four tasks of Phase A and subsequent random draw of a ball from the corresponding urn, in order to determine subjects' earnings in Phase A*]

[*Sum of the earnings in Phase A and Phase B individually and privately paid in cash to each subject*]

[*Charities' earnings in Phase B transferred to the chosen charities through on-line donations on behalf of the corresponding subject*]

[*On-line donation receipts sent by E-mail to the subjects within 24 hours after the end of the experiment*]

An Experimental Test of the Under-Annuitization Puzzle with Smooth Ambiguity and Charitable Giving

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Online Appendix C

Charity-specific, altruistic and idiosyncratic variables	Chosen Charity		Mann-Whitney test
	International	*National/Local*	*p-value*
Charity Known Years	3.27 [3.21]	3.10 [3.00]	0.510 [0.448]
Charity No. Previous Donations	0.69 [0.60]	0.89 [0.97]	0.438 [0.362]
Charity Participation	0.18 [0.16]	0.33 [0.34]	0.083 [0.067]
Charity Relatives-Friends	0.16 [0.18]	0.27 [0.29]	0.311 [0.061]
Altruism Own	5.91 [5.67]	6.16 [6.06]	0.348 [0.313]
Altruism Others	4.44 [4.28]	4.51 [4.49]	0.944 [0.760]
Time Discounting	49.9 [53.0]	54.0 [55.1]	0.604 [0.787]
Female	0.42 [0.42]	0.40 [0.37]	0.683 [0.674]
Age	1.72 [1.77]	1.90 [1.94]	0.170 [0.192]
Graduate	0.22 [0.21]	0.25 [0.29]	0.405 [0.437]
Economics	0.51 [0.53]	0.60 [0.69]	0.259 [0.179]

Table C.1. Average charity-specific, altruistic, and other features, disentangled by chosen charity. *Note*: For each average and test, the first value refers to the whole sample of 100 subjects. The second value, in square brackets, refers to the sub-sample of 78 rational-KMM-coherent subjects.

In Table C.2, we run a test of H0.i by using the fact that a subject has chosen a national or local rather than an international charity as a feature of higher warm-glow altruism toward that charity. The intuition behind this alternative test relies on the literature of charitable giving. In fact, it is well known in this literature that donors have a 'need to belong' (Sargeant 2008), *i.e.*, they need to feel that they are part of the charity. They should not just give to the charity, they should feel as a 'charity sponsor' or 'charity supporter'. However, it is not enough for them to feel how similar they are to the organization. They need to experience this for themselves. That is why charities try to involve their donors to take part in events and activities that let them experience similar beliefs and values being applied.

Raw statistics in Table C.1 seems to confirm the above intuition: in real-life bequest decisions, international charities are more often chosen for reputation or loyalty reasons (in Table C.1, the number of years a subject knew the chosen charity is higher, although not significantly, for international charities). National or local charities are instead chosen more often because of personal involvement and/or because a friend or relative is involved in or concerned by their activity. In fact, in Table C.1 the fraction of subjects who participated in the activities of the chosen charity is significantly higher among those who chose a national or local rather than an international charity. Furthermore, around 1/4 subjects choosing national or local charities had relatives or friends directly concerned by these charities; this fraction is lower across subjects choosing international charities. Table C.1 also shows a higher (although, again, non-significantly) average number of previous donation to national or local charities than to international ones.

In the OLS regressions of Table C.2 we introduce the dummy variable *High Investment* that takes value 1 if the investment in annuity in period 1 is at least 5, and 0 otherwise. Rather than the answers to the charity-related questionnaire (variables *Charity Known Years*, *Charity No. Previous Donations*, *Charity Participation*, and *Charity Relatives-Friends* in Table C.1), here we use the interaction between the former *High Investment* and another dummy variable, namely *National*, that takes value 1 if the chosen charity is a local or national charity, and 0 otherwise. We find that the interaction between a high investment in annuity in period 1 and the previous choice of a national rather than an international charity significantly increases the voluntary donation in period 2.

Dep. var.: Voluntary Donation		All Subjects		Positive Warm Glow	
High Investment * National Charity					
0	1	0.94	(1.36)	0.63	(1.31)
1	0	1.10	(1.06)	1.18	(1.02)
1	1	2.17 **	(1.06)	1.93 *	(1.05)
Altruism Own		0.24	(0.17)	0.17	(0.18)
Altruism Others		0.12	(0.16)	0.10	(0.15)
Risk Aversion		0.38	(0.60)	–0.18	(0.58)
Time Discounting		–0.01	(0.01)	–0.00	(0.01)
Female		–0.31	(0.64)	–0.36	(0.61)
Age		–0.07	(0.49)	0.01	(0.45)
Economics		–0.10	(0.62)	–1.41 **	(0.63)
Treatment		–0.56	(0.62)	–0.65	(0.61)
Constant		1.58 (1.91)		3.67 * (1.92)	
Adj. R-squared		0.011		0.075	
No. of observations		100		85	

Table C.2. OLS regressions explaining voluntary donation as high investment in national charities.
Note: Standard errors in parentheses, * $p < 0.1$, **$p < 0.05$, *** $p < 0.01$

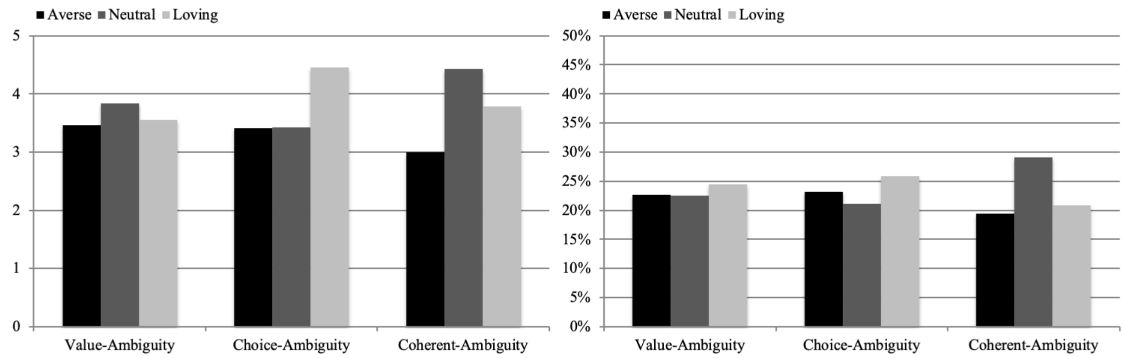

Figure C.1.Voluntary donation as absolute amount of wealth (left panel) and as share of wealth (right panel) if active in period 2, by ambiguity attitude, considering all sample of 100 subjects.

Dep. var.: Invested amount	Model I		Model II		Model III	
Coherent-Ambiguity Aversion	–3.46 ***	(0.94)	–3.21 ***	(0.90)	–3.26 ***	(0.92)
Charity Known Years	–0.04	(0.30)	–		–0.02	(0.32)
Charity No. Previous Donations	–0.05	(0.35)	–		–0.13	(0.35)
Charity Participation	–0.55	(1.09)	–		–1.58	(1.19)
Charity Relatives-Friends	0.37	(1.17)	–		0.68	(1.16)
Altruism Own	–0.04	(0.22)	–		–0.08	(0.22)
Altruism Others	0.05	(0.25)	–		0.02	(0.25)
Risk Aversion	–		–0.69	(0.90)	–0.63	(0.90)
Time Discounting	–		–0.01	(0.01)	–0.01	(0.01)
Female	–		0.79	(0.94)	1.05	(1.01)
Age	–		0.90	(0.66)	1.45 *	(0.78)
Economics	–		0.14	(0.92)	0.20	(1.00)
Treatment	–		–0.03	(0.93)	0.42	(1.00)
Constant	9.19 ***	(1.90)	7.96 ***	(2.59)	6.80 **	(3.21)
Log likelihood	–122.92		–120.68		–119.50	
No. of observations	57		57		57	

Table C.3. Tobit regressions explaining the amount invested by rational-KMM-coherent subjects in period 1 of phase B, by excluding subjects with investment $a = 5$ in annuities.

Note: Standard errors in parentheses, * $p < 0.1$, **$p < 0.05$, *** $p < 0.01$

Dep. var.: Invested amount	Model I		Model II		Model III	
Value-Ambiguity Aversion	–0.31 **	(0.12)	–0.44 ***	(0.12)	–0.45 ***	(0.13)
Charity Known Years	–0.06	(0.21)	–		–0.03	(0.22)
Charity No. Previous Donations	0.11	(0.25)	–		–0.02	(0.24)
Charity Participation	–0.27	(0.68)	–		–0.87	(0.68)
Charity Relatives-Friends	–0.17	(0.69)	–		–0.12	(0.65)
Altruism Own	0.03	(0.16)	–		0.01	(0.16)
Altruism Others	–0.08	(0.15)	–		–0.14	(0.15)
Risk Aversion	–		–0.99 *	(0.59)	–1.07 *	(0.60)
Time Discounting	–		0.00	(0.01)	-0.00	(0.01)
Female	–		0.66	(0.59)	0.86	(0.61)
Age	–		0.87 **	(0.41)	1.04 **	(0.44)
Economics	–		–0.67	(0.55)	–0.68	(0.60)
Treatment	–		–0.08	(0.55)	0.02	(0.55)
Constant	6.90 ***	(1.20)	5.52 ***	(1.40)	6.11 ***	(1.83)
Log likelihood	–222.11		–216.77		–215.45	
No. of observations	100		100		100	

Table C.4. Tobit regressions explaining the amount invested by subjects in period 1 of phase B, considering the degree of **value**-ambiguity aversion of all the 100 subjects.

Note: Standard errors in parentheses, * $p < 0.1$, **$p < 0.05$, *** $p < 0.01$

Dep. var.: Invested amount	Model I		Model II		Model III	
Choice-Ambiguity Aversion	–0.23 **	(0.10)	–0.21 **	(0.10)	–0.21 **	(0.10)
Charity Known Years	0.03	(0.21)	–		0.02	(0.23)
Charity No. Previous Donations	–0.03	(0.24)	–		–0.18	(0.24)
Charity Participation	0.01	(0.69)	–		–0.27	(0.71)
Charity Relatives-Friends	–0.28	(0.70)	–		–0.30	(0.68)
Altruism Own	0.02	(0.16)	–		–0.02	(0.16)
Altruism Others	–0.13	(0.15)	–		–0.20	(0.15)
Risk Aversion	–		–0.08	(0.57)	–0.05	(0.57)
Time Discounting	–		-0.00	(0.01)	–0.00	(0.01)
Female	–		0.10	(0.59)	0.41	(0.64)
Age	–		0.72 *	(0.43)	0.89 *	(0.46)
Economics	–		–0.51	(0.58)	–0.59	(0.62)
Treatment	–		–0.31	(0.58)	–0.29	(0.58)
Constant	6.93 ***	(1.21)	5.99 ***	(1.49)	6.86 ***	(1.92)
Log likelihood	–222.72		–220.67		–219.24	
No. of observations	100		100		100	

Table C.5. Tobit regressions explaining the amount invested by subjects in period 1 of phase B, considering the degree of **choice**-ambiguity aversion of all the 100 subjects.

Note: Standard errors in parentheses, * $p < 0.1$, **$p < 0.05$, *** $p < 0.01$