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Abstract

We combine experimentally elicited preferences with administrative micro data to study actual financial decision-making. Firstly, we simultaneously elicit and estimate risk and time preferences in a real-life context, with horizons up to 10 years, for more than 1000 pension fund participants. We estimate a present-bias factor of 0.84, an annual discount rate of 1.1%, and a CRRA utility curvature of 0.97. Secondly, using an expected utility framework, we show that the individually estimated preferences explain actual retirement decisions up to 82% of our sample for a utility indifference of at most 2% annual certainty equivalent consumption. Freedom of choice by means of a front-loaded annuity creates annual potential welfare gains up to 2.77%, but realized welfare gains are lower or even negative.

Keywords: occupational pension, annuity, convex time budgets, risk and time preferences

JEL Codes: D14, D15, D81, D91, H55, J26

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I. Introduction

Risk and time preferences play a role in almost every economic decision. As a consequence, understanding individual risk and time preferences is intimately linked to understanding economic behavior. Over the past decades, researchers have been studying the explanatory power of risk and time preferences for economic behavior. However, most previous research relies on stated economic behavior, independently measured risk and time preferences that are context independent, and the explanatory power is studied through correlations.

In this paper, we simultaneously measure risk and time preferences among pension fund participants in the same context in which we observe actual annuitization decisions. To simultaneously elicit and estimate preferences, we use the Convex Time Budgets (CTB) method of Andreoni and Sprenger (2012a). Because risk and time preferences are domain specific (Frederick et al., 2002; Schildberg-Hörisch, 2018; Cohen et al., 2020), we measure risk and time preferences in a pension context with large experimental budgets and long decision horizons similar to our observed real-life choice. We study how well these domain-specific structurally estimated preferences explain actual real-life annuity choices rather than stated choices. We use an integrated discounted expected utility framework with the domain specific estimated preferences simultaneously as inputs. Our approach differs from the previous literature, as typically a linear correlation between each generalized preference parameter and domain-specific actual behavior is used to independently assess the explanatory power of each preference parameter (Dohmen, Falk, Huffman, Sunde, et al., 2011; Sutter et al., 2013; Cohen et al., 2020).

In the analysis, we use a large-scale non-student sample of 1062 pension fund participants. The individuals are invited by the pension fund and in our online CTB experiment they allocate €10,000 between an early payment and a late payment ten years in the future. We can expect individuals to spend more effort in thinking about their choice than in a laboratory with small stakes, no pension context, and shorter horizons. The preferences that we measure are present bias, long-term patience, and CRRA utility function curvature. We combine the individually estimated preferences with a detailed dataset on personal characteristics and actual annuitization decision of retirees, such that we can study to what extent risk and time preferences explain actual financial decision making. The actual financial decision concerns a choice between a flat annuity with equal life-long payments throughout the retirement phase, and a front-loaded annuity with higher payments during the first retirement years and actuarially fair lower life-long payments till death.

We study actual annuitization decisions in the context of risk and time preferences, because it appears intuitive that impatient individuals and those with curvature parameters close to unity (i.e., they are risk neutral and don't mind a less smooth consumption path) might prefer a front-loaded annuity. A front-loaded annuity is comparable to a lump sum, as it allows the beneficiary to receive pension payments earlier and higher compared to a flat annuity. On the other hand, individuals that care more about the future and prefer smooth consumption paths might prefer a flat annuity with equal payments during retirement. Thus, in line with Brown (2001), risk and time preferences are plausible and important channels for the annuitization decision. Besides the predictive power of preferences for annuity choices, we also quantify the welfare implications that emerge through the freedom of choice between a flat and front-loaded annuity.

The Dutch pension fund's data has several advantages compared to other data sources. First, the dataset includes actual real-life annuity choices rather than incentives, attitudes, or stated preferences on economic decision making. Second, the dataset provides detailed and reliable information on the participants and the pension plans, which is often hard to ask in surveys. For example, we can correct the payment schemes by life expectancy that is fund specific for age, cohort, and gender. Third, the annuity decision involves large stakes with long decision horizons, similar to our experiments on risk and time preferences. Finally, the Dutch annuity decision reflects global pension choices, as near retirees often have to make a choice between an annuity or lump sum.

Our results imply for the quasi-hyperbolic discounting model (also known as the $\beta - \delta$ model) a median present-bias factor of 0.84, a median annual discount rate of 1.1%, and a median CRRA utility curvature of 0.97. We find evidence for present bias, since the present-bias factor $\beta < 1$. Our finding is consistent with the general observation of substantial present bias in the literature (Frederick et al., 2002). The estimated median curvature of the CRRA utility function is somewhat lower than linear utility and, thus, implies a preference for smooth consumption paths, which is similar to previous estimates (Andreoni and Sprenger, 2012a; Potters et al., 2016). Note that in the literature risk aversion over states of the world tends to deviate more from linear utility (Cheung, 2020).

Our risk and time preference estimates are comparable to previous estimates in the literature (Andreoni and Sprenger, 2012a; Andersen, Harrison, Lau, et al., 2014; Balakrishnan et al., 2020). This is interesting in itself, because previous studies that jointly estimate risk and time preferences frequently use laboratory settings without a specific context based on student samples. However, our estimated discount rate differs from most previous findings. Our estimated annual discount rate is in line with market interest rates and is lower than estimates in most previous research. Estimates of annual discount rates from 30%-100% are not uncommon (Frederick et al., 2002; Andreoni and Sprenger, 2012a; Cheung, 2020). Potential reasons for our lower estimated discount rate are the magnitude of the experimental budget and the long-term decision horizons (Thaler, 1981). Laboratory experiments typically have short decision horizons that run from several weeks to several months (Andersen, Harrison, M.Lauc, et al., 2010; Tanaka et al., 2010; Augenblick, Niederle, et al., 2015), but do not exceed more than 3 years (Harrison et al., 2002; Goda et al., 2015). Moreover, the typical experimental payment equals tens of dollars (Andreoni and Sprenger, 2012a), rather than ten thousand dollars.

The second set of results shows that our individually estimated risk and time preferences explain real-life financial decisions to a large extent. Using a simple univariate analysis, we find that patient individuals with a preference for smooth consumption paths choose a flat annuity, while present-biased and impatient individuals with a higher CRRA curvature choose a front-loaded annuity to withdraw more pension wealth during the early years of retirement. Using a discounted expected utility framework, we find that risk and time preferences explain actual annuitization decisions for 82% of our population for a utility indifference of at most 2% annual certainty equivalent consumption. This so-called 'indifference bandwidth' resembles a prediction error and indicates the annual consumption loss between the actually chosen and unchosen counterfactual annuity. Because a flat and front-loaded annuity might be observationally equivalent in terms of utility for a retiree, we study the predictive power of preferences if small consumption losses are allowed.

To our knowledge, no previous paper has related simultaneously estimated risk and time preferences to actual financial decision making by means of a utility framework that uses risk and time preferences simultaneously. Most previous papers assess how predictive each separate preference is by correlations from multivariate linear regression analysis (Cohen et al., 2020) or through self-reported behavior. Dohmen, Falk, Huffman, and Sunde (2010) relate risk and time preferences separately to cognitive ability, while Dohmen, Falk, Huffman, Sunde, et al. (2011) correlate general and domain specific risk aversion to self-reported field behavior. Chabris et al. (2008) study correlations between laboratory-measured time preferences and self-reported behavior (e.g., BMI, smoking, exercise, saving, and gambling), and Golsteyn et al. (2014) study correlations between children's categorically measured time preferences and observed economic outcomes (e.g., schooling, health, labour, and income) later in life. Sutter et al. (2013) study how independently measured risk and time preferences correlate independently with self-reported behavior (e.g., health, savings, and schooling) amongst children and adolescents. Falk et al. (2018) study how independently measured risk and time preferences correlate separately with economic outcomes amongst individuals worldwide. Bütler and Teppa (2007) study actual observed annuitization decisions at retirement rather than stated behavior, but their data lacks individual preference parameters. Hurwitz and Sade (2020) study the annuity versus lump sum decision through the mechanism of smoking. Furthermore, implicit in laboratory elicited preferences is the assumption that laboratory results are a reliable assessment of general behavior, even though we know that the typical subject pool is different from the population to which they are being applied (Andersen, Harrison, M.Lauc, et al., 2010). We overcome this problem by eliciting preferences and observing behavior directly in the same population and domain.

The third set of results shows that freedom of choice by means of a front-loaded annuity creates potential welfare gains, but part of the welfare remains unrealized. Given the predictive power of preferences for actual annuity choices, we perform a welfare analysis to investigate the effects of introducing freedom of choice in the annuity decision. Specifically, we quantify the welfare effects of the front-loaded annuity option from a long-run persistent point of view, i.e., setting the present-bias factor to dynamically consistent behavior $\beta = 1$. The estimated mean conditional potential welfare gain of a front-loaded annuity ranges from 1.61% to 2.77% additional annual consumption, depending on the indifference bandwidth. The welfare distributions show that realized welfare can be negative and, thus, causes welfare losses. Overall, these findings can have important policy implications.

II. Methodology

To measure risk and time preferences, we field a survey at a large pension fund in The Netherlands. The survey implements the experimental CTB method (Andreoni and Sprenger, 2012a; Andreoni and Sprenger, 2012b) and a present-bias task (Frederick, 2005; Rieger et al., 2015; Wang, 2017). We relate the elicited preferences to actual pension choices of retirees.

A. Elicitation of risk and time preferences

We use the CTB to elicit patience and utility curvature, and we use an additional present-bias task to elicit present bias. Next, we adopt a simultaneous estimation technique to estimate utility curvature, patience, and present bias together. The advantage of our approach is a simultaneous measurement of risk and time preferences. For this reason, we avoid the assumption of linear utility and, consequently, we avoid upward-biased discount rate estimates if true utility is concave (Andersen, Harrison, Lau, et al., 2008; Noor, 2009).

The CTB method asks individuals to allocate an initial budget $m =$ €10.000 between payments, available at two points in time: an early payment at time t and a delayed payment at time $t + k$. In line with Potters et al. (2016), the early payment is always one year $t = 1$ from the experimental date, and the late payment is delayed by ten years $k = 10$. The delay length is relatively long and selected such that we can study decision making under uncertainty for long horizons. Subjects receive an interest rate r on delayed payments, which varies between 0% to 8.40% on an annual basis. The allocations must be made such that the budget constraint is satisfied, i.e., the early payment and the present value of the delayed payment must equal the initial budget m. Early payments are certainly paid (i.e., payment probability one), but delayed payments have a payment probability p_{t+k} of 0.5, 0.75, 0.90, or 1.

Individuals make 20 consecutive CTB decisions between early and delayed payments. Our method consists of four different decision sets. Each decision set has a different probability of late payment, and within each set we have five different interest rate scenarios. The difference between the early payment date t and the delayed payment date $t + k$ elicits long-term patience, similar to Andreoni and Sprenger (2012a). We identify risk preferences by sensitivities to variation in the interest rates, similar to Andreoni and Sprenger (2012a), but also by sensitivities to the late payment probability (i.e., states of the world). Thus, we extend the original CTB approach of Andreoni and Sprenger (2012a). Table 6 in Appendix A presents an overview of our experimental design.

To identify present bias, we implement a task in our experiment from the INTRA (International Test of Risk Attitudes) study, conducted by the University of Zurich and used by Rieger et al. (2015) and Wang (2017). This task is inspired by Frederick (2005), and reads as follows:

> *Enter an amount $c_{t+\tau}$ such that option B is as attractive as option A:*
> A. Receive €800 now,
> B. Receive € $c_{t+\tau}$ next year.

Subjects make a trade-off between a direct payment of €800 now or a later certain payment c_1 next year. Due to the implementation of an immediate payment now combined with the long-run decisions from the CTB, we can elicit and estimate the (present-biased) time preferences for every subject while controlling for utility curvature. Table 6, Scenario 21, summarizes the present-bias task.[1]

B. Experimental procedure

The CTB experiment and present-bias task are part of a larger survey. We wrote a Qualtrics program to implement the survey. In the first part of the survey, we ask subjects for personal information, such as pension attitudes, demographics (age, education), and financial situation (income, housing wealth). The second part of the survey contains the CTB experiment and, then, the present-bias task. Subjects could go through the survey, including the experiment, at their own pace, also going back and forth through the questions. In the email, and at the end of the survey, we announce that subjects are able to receive one out of five vouchers with a value of €50. The voucher will be received via email, implying that subjects need to enter their email address. The survey questions are shown in the Online Appendix.

Although the questions were not directly incentivized, the pension fund indicated in the instructions that the results would be taken into account to study the desirability of choice options, so participation in the survey was consequential. Our experiment is not incentivized based on the experimental answers of the subjects, which avoids the need for complex equalization of payments, transaction costs and payment confidence. Some researchers argue that answer-based incentives in economic experiments lead to more truthful reveal of preferences,

[1] The original question is in US dollars. The monetary payoff of €800 in our scenario is adjusted according to the currency exchange rate in 2018 and the Purchasing Power Parity (PPP) in The Netherlands.

however Cohen et al. (2020) and Hackethal et al. (2022) find little evidence for systematic differences between incentivized and unincentivized risk and time preference experiments. More specifically, Potters et al. (2016) find little differences between financially incentivized and hypothetical decisions in their CTB experiments.[2]

Upon starting the experiment, subjects read through the instructions and a CTB example decision screen. These indicated to the subjects that the budget could be entirely allocated to the early payment (corner), entirely to the later payment (corner) or divided between the two (interior). Figure 1 shows an image of a decision screen. The decision screen contains a timeline of the payment structure: 2018 is the experimental date, the early payment is received in 2019 and the late payment is received in 2029 after an additional delay of ten years. Subjects are told to divide the amount of €10,000 between the early payment and late payment. Probabilities of late payment and interest rates were highlighted by yellow and blue, respectively. In this particular decision screen, the likelihood that the late payment is paid equals $p_{t+k} = 100\%$ and there are five budget decisions presented in order of increasing gross interest rates from 1.00 to 1.59. Subjects are faced with a total of four such decision screens, corresponding to the four probability decision sets. After the twenty CTB decisions, subjects complete the present-bias task.

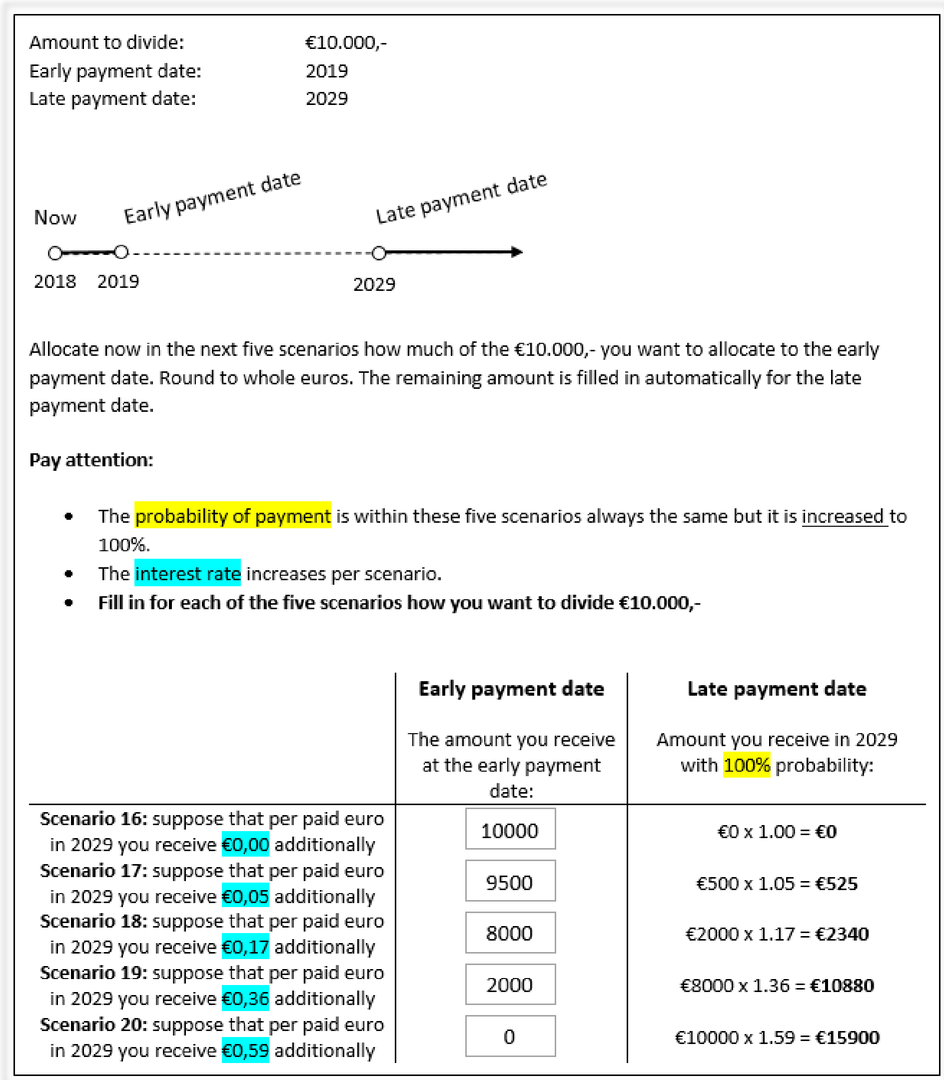
We fielded our survey at the pension fund ABP in The Netherlands.[3] The pension fund has a panel for experimental research and communicates via email. The invitations for our experiment and the experiment itself were simultaneously conducted in the period 13 August 2018 till 17 September 2018. Individuals could join the experiment by clicking on a link in the email.

C. Annuity choices

The Dutch pension system has two main pillars: (i) a publicly financed pay-as-you-go scheme and (ii) a mandatory occupational pension scheme. The first pillar, or General Old-Age Pensions Act, aims at providing a minimum retirement income, and is funded from tax revenues. Individuals receive first-pillar benefits when they reach the statutory retirement

[2]Another review by Camerer and Hogarth (1999) finds that incentives do not reliably change average performance, but tend to decrease the variance of responses. Since our sample is relatively large, this decreases the variance of the preference estimates on an aggregate level.

[3]ABP is the largest pension fund in The Netherlands. The abbreviation translates to National Civil Pension Fund, and arranges the pensions for mainly civil servants.



Amount to divide: €10.000,-
Early payment date: 2019
Late payment date: 2029

Now · Early payment date · Late payment date
2018 · 2019 · 2029

Allocate now in the next five scenarios how much of the €10.000,- you want to allocate to the early payment date. Round to whole euros. The remaining amount is filled in automatically for the late payment date.

Pay attention:

- The probability of payment is within these five scenarios always the same but it is increased to 100%.
- The interest rate increases per scenario.
- **Fill in for each of the five scenarios how you want to divide €10.000,-**

	Early payment date The amount you receive at the early payment date:	**Late payment date** Amount you receive in 2029 with 100% probability:
Scenario 16: suppose that per paid euro in 2029 you receive €0,00 additionally	10000	€0 x 1.00 = **€0**
Scenario 17: suppose that per paid euro in 2029 you receive €0,05 additionally	9500	€500 x 1.05 = **€525**
Scenario 18: suppose that per paid euro in 2029 you receive €0,17 additionally	8000	€2000 x 1.17 = **€2340**
Scenario 19: suppose that per paid euro in 2029 you receive €0,36 additionally	2000	€8000 x 1.36 = **€10880**
Scenario 20: suppose that per paid euro in 2029 you receive €0,59 additionally	0	€10000 x 1.59 = **€15900**

Figure 1: **Decision screen Convex Time Budgets.** In this decision screen, the subject allocates $m = 10.000$ Euro between an early payment with front-end delay $t = 1$ (2019) and a late payment with back-end delay $k = 10$ years (2029). The late payment is with a probability p_{t+k} of 100%. The gross interest rate $1 + r$ over k years in the 5 scenarios varies from 1.00 to 1.59. The allocated amounts are for illustration purposes only, the default values were blanks (subjects must actively allocate). The text is translated from Dutch to English.

age, which is 66 years in 2018. The majority of the active participants with an uninterrupted working career qualify for a benefit close to the maximum yearly amount of €14,000 for single individuals and roughly €18,000 for couples. First pillar benefits are indexed based on price inflation, and always paid out as life-long annuities.

The second pillar is an employer-based occupational pension scheme that features collectivity, mandatory participation, and is not for profit. Pension funds operate on the basis of capital funding: an employee, together with her employer, accrues pension entitlements from the contributions paid in and the return realized by the pension fund over the years through the collective investment of these contributions. The main goal is to maintain the pre-retirement living standards, together with the benefits from the first pillar. We study the freedom of choice that retirees have in the second pillar through their annuity choices in the occupational pension scheme.

The individual's annuity decision has three key components, and the choice can only be made once. The individual must make a choice regarding (i) the date of retirement, (ii) a bridging pension or not, and (iii) the payment profile.[4] Regarding key decision (i), the individual must decide when to retire, e.g., at the statutory retirement age (i.e., the default) or earlier.[5] Retiring earlier than the statutory retirement age decreases overall monthly life-long benefits at an actuarially fair rate, because the individual starts to withdraw her pension wealth earlier than the statutory retirement age.

Regarding key decision (ii), the pension fund offers the beneficiary the option to receive a so-called bridging pension (i.e., the default option) until the statutory retirement age is reached, i.e., the moment when she receives first-pillar pension benefits. The goal of a bridging pension, only available when retiring early, is to ensure a flat payment stream of benefits before and after the statutory retirement age. When choosing a bridging pension on top of early retirement, the individual depletes her second-pillar pension wealth faster compared to no bridging pension, so that overall monthly life-long benefits are reduced at an actuarially fair rate.

Regarding key decision (iii), the fund offers the possibility to increase benefits for 5 to 10 years at any point during the retirement phase.[6] The idea is that individuals can construct a high-low stream of payments to tailor pension benefits to the individual's needs. A high-low construction frontloads the pension benefits, like a lump sum, and it could be

[4]There is also the possibility to exchange partner pension for old-age pension, but we exclude this in our analysis as we study individual decisions.

[5]Individuals can also retire later than the statutory retirement age, but almost no individual does so.

[6]Legally, pension benefits can be increased (or decreased) until the age of 78.

used for paying off a mortgage or travel plans.[7] Of course, a high-low construction depletes second-pillar pension wealth faster than constant annuity payments and, thus, reduces future monthly life-long benefits at an actuarially fair rate. The legal condition states that the lower benefits must at least equal 75% of the higher benefits. The default is no frontloading of pension payments.

So, the retiree constructs her own annuity based on the three choices. At least 6 months before the statutory retirement age the individual receives information from the fund about her annuitization decision (unless she made a choice already). Essentially, the pension fund offers the possibility to withdraw the accumulated capital either as a *flat* life-long annuity or as a *front-loaded* life-long annuity. We label an annuity as front-loaded if the retiree within one year after her pension age has at least 1 year of after-tax pension benefits that are 5% higher than payments in the future years, taking first pillar pension benefits into account.[8] We label an annuity as flat otherwise.

The majority of individuals in our sample that choose a front-loaded annuity construct the annuity such that high payments start within 1 year after retirement with an average duration of 3 years and low payments equalling the legal minimum 75% of the high payments. Examples of a front-loaded annuity include early retirement with bridging pension and high-low payments, or retirement at the statutory retirement age with high-low payments. While examples of a flat annuity include retirement at the statutory retirement age (default), or early retirement with bridging pension and constant payment afterwards (i.e., not front-loading payments). If individuals forego to make an active annuitization decision, then the fund offers by default a flat life-long annuity starting at the statutory retirement age.

D. Sample

In total, 6225 pension fund participants clicked on the link in the email to participate in our survey. For our current research, we select pension fund participants between the ages of 50 years and 70 years, as these cohorts are most likely concerned with their pension choices and individuals with ages below 50 did a different experiment. This leads to a sample of 3611

[7]The pension fund also offers the possibility to construct a low-high payment stream that backloads future pension benefits, for example to facilitate later (unexpected) health costs. However, few individuals choose a low-high payment structure in The Netherlands.

[8]We use a threshold of 5%, because due to administrative reasons flat annuity payments could fluctuate within this bandwidth.

individuals. Additionally, we exclude 11 retirees with a pension date that is later than the statutory retirement age and we exclude 48 retirees with a back-loaded annuity, as we want to specifically study front-loading behavior, which yields 3552 individuals. Furthermore, we drop individuals that did not complete the present-bias task, CTB experiment, or filled the same early payment amount in every CTB scenario. For these individuals we cannot estimate the preference parameters. Finally, we drop individuals that entered an amount next year $c_{t+\tau}$ that is lower than receiving €800 now, or entered an amount next year $c_{t+\tau}$ that is lower than receiving an amount in 10 years, as these answers imply negative interest rates.[9] Overall, this yields a final sample of 1062 individuals.

We are aware that we lose quite some observations in the sample selection. However, there is still lots of heterogeneity in our sample. Eventually, it is this heterogeneity that matters for studying the relation between preferences and real-life choices. Moreover, our sample is still representative for the pension fund based on several important variables.

Table 1 compares our sample of subjects with the pension fund's population from 2018, restricted to the ages of 50 and 70.[10] In our sample, 705 respondents are so-called active participants. These active participants actively accrue pension rights at the pension fund through their employer. 357 respondents are retirees, who receive pension benefits from the pension fund. Panel A shows that the male-to-female and active-to-retiree ratios are nearly equal between the fund and our sample. Because we study actual pension choice behavior of retirees later, we present additional summary statistics on the retired population in Panel B. The median age of the retired subjects in our sample is almost similar to the pension fund's value of 67. The male respondents in our sample are more likely to have a somewhat higher income, but the female income is nearly identical to the pension fund's value.[11] The median time taken to complete the survey, including the questions on personal and financial information, is 20 minutes. The participants understood the CTB experiment generally well, as the median rating for the difficulty of the CTB experiment is 3 (i.e., "not easy, but also not difficult") on a 5-point Likert scale.[12]

[9] To check the understanding of participants, subjects also answer how much money they would like to receive in 10 years which makes them indifferent with receiving €800 now.

[10] We focus on old-age pension for the pension fund's retirees.

[11] Table 9 in the Online Appendix provides additional summary statistics on demographic, financial and pension variables. Tables 10 and 11 in the Online Appendix describe the definitions of all variables used in our analysis.

[12] The question regarding the difficulty of the CTB experiment follows immediately after the CTB exper-

Table 1: **Summary statistics.** This table presents summary statistics for our sample and the pension fund. Panel A contains all subjects, i.e., active participants and retirees. Panel B contains only retirees. *Male* and *Retired* are dummy variables. *Age* is in years and *Income* is the annual before-tax income in Euros, which includes all employer-related second pillar pension benefits received from the pension fund including state pension benefits. Standard deviation between parentheses.

Panel A: Active participants and retirees				
		Pension fund	Sample mean	*N*
Male		0.567	0.570 (0.500)	1062
Retired		0.384	0.340 (0.470)	1062
Panel B: Retirees				
		Pension fund	Sample median	N
Age (years)	Male	67.31	67.15 (1.84)	240
	Female	67.14	67.27 (2.36)	117
	Total	67.24	67.20 (2.03)	357
Income (€)	Male	22,670	28,358 (16,587)	217
	Female	16,637	16,739 (12,225)	104
	Total	20,102	23,317 (16,199)	321

III. Preferences

In this section, we firstly present the aggregate choice behavior in the CTB and present-bias task. Then, we discuss the simultaneous estimation of individual risk and time preferences. Finally, we show the estimation results for the preference parameters.

iment. See Table 9 in the Online Appendix for additional summary statistics.

A. Descriptive analysis

First, we describe the choice behavior in the CTB and, then, in the present-bias task. Figure 2 summarizes aggregate choice behavior in the CTB for the whole population (i.e., actives and retirees combined). We plot the median allocated Euros chosen at the early payment c_t against the gross interest rate $(1 + r)$ for each late payment probability p_{t+k}. The amount of Euros allocated to the early payment declines monotonically with the interest rate, indicating that people wait for the late payment when interest rates are higher. Additionally, as expected, the amount of earlier Euros increases when the late payment probability is lower. So, we observe in Figure 2 that individuals respond to changing interest rates and payment probabilities in a predicted way.

Figure 2: **Choice behavior: Convex Time Budgets.** Median allocated Euros at early payment c_t against the gross interest rate $1 + r$ per payout probability p in the Convex Time Budgets.

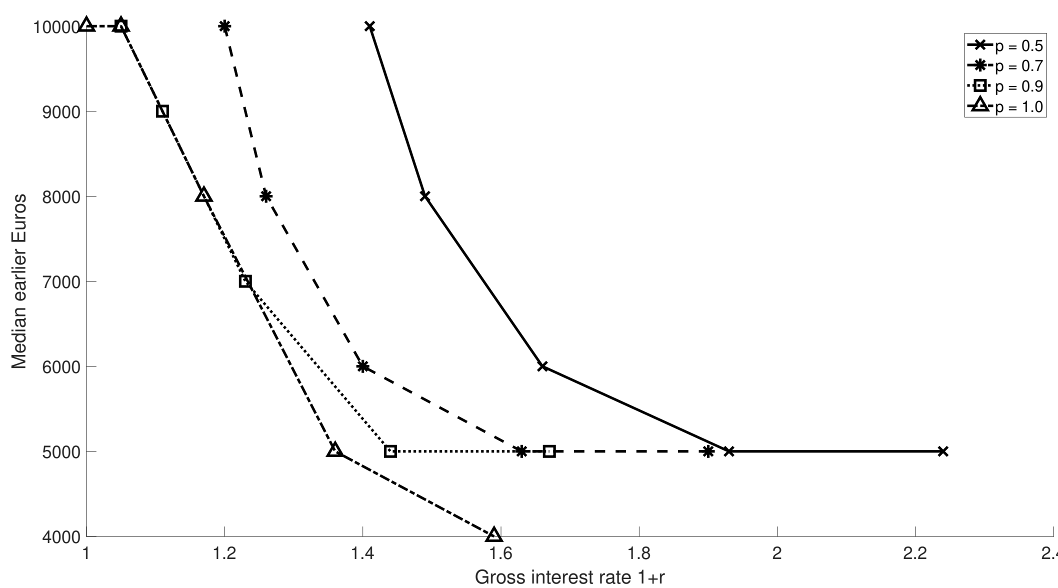


Figure 3 summarizes aggregate choice behavior in the present-bias task, for actives and retirees separately. The subjects' answers are winsorised at a 5% level from the bottom and the top of the distribution. The dashed red bars depict retirees, while the solid gray bars depict active participants. The upper panel reports the allocated amount $c_{t+\tau}$ in Euros that makes subjects indifferent between receiving €800 now or receiving $c_{t+\tau}$ next year. The fraction of retirees that allocates lower amounts of wealth $c_{t+\tau}$ to next year (e.g., between €800 and €1000) to make them indifferent with €800 directly is larger than for actives. This is preliminary evidence that actives are more impatient than retirees in the short trun.

The bottom panel reports the implied annual interest rates based on the allocated amounts $c_{t+\tau}$. A high interest rate indicates that the subjects discount consumption next year heavily. For about 70% (75%) of the actives (retirees), the annual interest rates from the one-year present-bias task are larger than 10%. This is higher than the annual interest rates in the ten-year CTB task, which vary from 0 to 8.40 percent per year.[13] Thus, in line with Thaler (1981), we find that discount rates elicited in the short run are higher than discount rates elicited in the long run. This observation provides evidence for time inconsistency and indicates the possibility of present bias for pension fund participants. More specifically, in line with the upper panel, the bottom panel shows that active participants are more prone to present-biased behavior than retirees as actives discount consumption next year more strongly. The effect is visible between the lower interest rates of 0% to 20%, where the fraction of retirees is higher, while for interest rates larger than 20% the fraction of active participants is higher.

B. Simultaneous estimation of risk and time preferences

To estimate risk and time preferences, we identify the experimental allocated payments as solutions to standard intertemporal optimization problems. These solutions are supposed to be functions of our parameters of interest (present bias, discounting, and utility curvature), and experimentally varied parameters (interest rates, delay lengths and payment probabilities). Given assumptions on the functional form of utility and the nature of discounting, our experimental tasks provide a natural context to jointly estimate individual preferences.

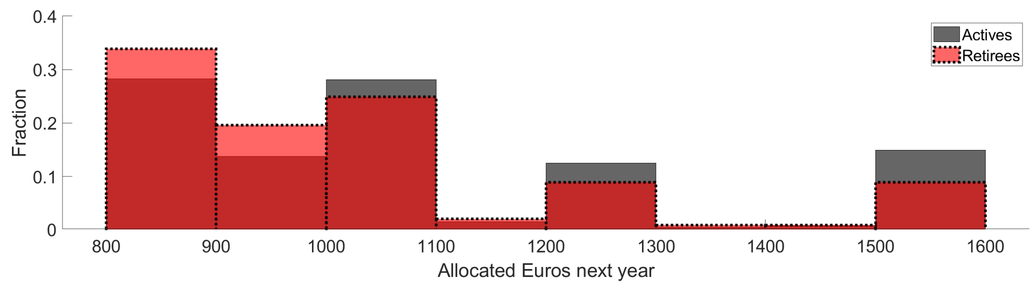
In the CTB, subjects choose an amount c_t, available at time t, and an amount c_{t+k}, available after a delay of k periods, continuously along a convex budget set

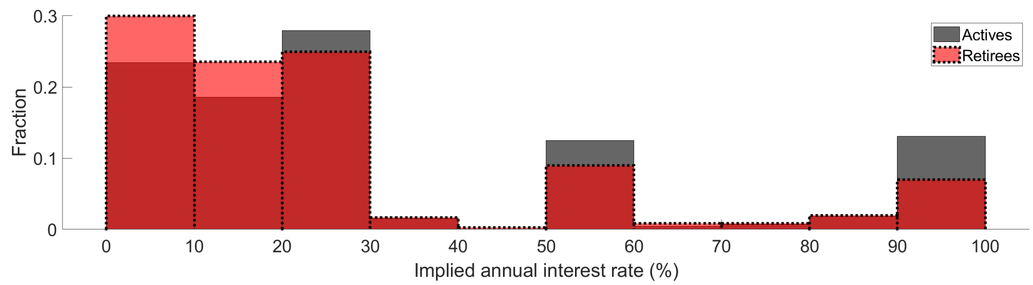
$$c_t + \frac{c_{t+k}}{1+r} = m, \tag{1}$$

where $(1 + r)$ is the experimental gross interest rate and m is the experimental budget.

[13]Figure 2 shows that the CTB design per se is not an issue, because the median amount allocated to the earlier payment is about €5000 which is not a corner solution.

Figure 3: **Choice behavior: Present-bias task.** Distribution of allocated Euros $c_{t+\tau}$ in the present-bias task, together with the implied annual interest rate. Implied annual interest rate calculated as $(c_{t+\tau}/800 - 1) \times 100$.





Money allocated to the early payment has a value of c_t, while money allocated to the late payment has a present value of $c_{t+k}/(1+r)$. c_{t+k}/c_t defines the gross interest rate $1+r$ over k years, so $(1+r)^{1/k} - 1$ gives the standardized annual interest rate r. Multiplication by the payment probability p_{t+k} defines the risk-adjusted interest rates.

Using the quasi-hyperbolic $\beta - \delta$ model of intertemporal decision making (Phelps and Pollak, 1968; Laibson, 1997), the subject maximizes discounted expected utility over the early payment c_t and late payment c_{t+k}

$$\max_{c_t, c_{t+k}} \delta^t U(c_t + w_t) + \beta \delta^{t+k} \left[p_{t+k} U(c_{t+k} + w_{t+k}) + (1 - p_{t+k}) U(w_{t+k}) \right], \tag{2}$$

where δ is the one period discount factor and β is the present-bias factor. The quasi-hyperbolic form captures the notion of time-inconsistent behavior, since $\beta < 1$ indicates present bias. Moreover, it nests exponential discounting (i.e. standard time-consistent behavior, Samuelson, 1937) when $\beta = 1$. Early payments are certain, while late payments can be uncertain such that with probability $1 - p_{t+k}$ no delayed payment is received. The terms

w_t and w_{t+k} could be interpreted as background consumption or income (see, e.g., Andersen, Harrison, Lau, et al., 2008).

We posit the agent has a time separable Constant Relative Risk Aversion (CRRA) utility function of the form

$$U(x) = \frac{1}{\alpha} x^{\alpha}, \tag{3}$$

where $\alpha < 1$ is the curvature of the CRRA utility function. Under discounted utility, $\alpha < 1$ implies concavity of instantaneous utility that captures resistance to intertemporal substitution, giving rise to a preference to smooth payoffs over time.

At times, the CRRA utility function is formulated as $U(x) = \frac{1}{1-\gamma} x^{1-\gamma}$, with γ the coefficient of relative risk aversion parameter of the individual. Under expected utility $\gamma > 0, \gamma \neq 1$, implies concavity that captures classical risk aversion, giving rise to a preference for more equally-distributed payoffs over states of nature. In principle, risk aversion and intertemporal substitution describe conceptually distinct preferences (Cheung, 2020). But, in our experimental setting, uncertainty in both risk and time are present, such that it is natural to assume that utility for risk is the same as instantaneous utility for time. Namely, in our CTB task, risk preferences are identified by changes in interest rates and uncertainty regarding delayed payments. Essentially, we ask subjects about the smoothness of payoffs over time and for different states of the world. This gives rise to discounted expected utility.[14]

Solving the subject's standard intertemporal maximization problem (2) subject to the budget constraint (1) yields the first-order condition

$$\left(\frac{c_t + w_t}{c_{t+k} + w_{t+k}} \right)^{\alpha - 1} = \begin{cases} \beta \delta^k p_{t+k}(1+r) & \text{if } t \in [0,1] \\ \delta^k p_{t+k}(1+r) & \text{if } t \geq 1 \end{cases} \tag{4}$$

Clearly, the experimental allocations depend on the parameters of interest (present bias, discounting, and curvature), and the experimentally varied parameters (interest rates, delay length, and payment probabilities). The present, i.e., $t \in [0,1]$, runs from the experimental

[14]In the literature, we find that concavity under discounted utility (i.e. over time) is less than concavity under expected utility (i.e. under risk), but curvature estimates significantly differ from linear utility as well (for example, see Andreoni and Sprenger, 2012a).

date at the end of 2018 (i.e., $t = 0$) till next year at the end of 2019 (i.e., $t = 1$), and afterwards the future starts.

Please note that for some CTB scenarios with uncertain late payment probabilities, decision sets 1 till 3 in Table 6 in the Appendix, the risk-adjusted interest rates are negative and the expected payment values are not always constant between the decision sets. Additionally, the present-bias task involves only payments with certainty.

Thus, taking the natural logarithm of (4), we find

$$\begin{aligned} \ln\left(\frac{c_t + w_t}{c_{t+k} + w_{t+k}}\right) &= \frac{1}{\alpha - 1}\left(\log(\beta) \cdot \mathbb{1}_{t\in[0,1]} + \log(\delta) \cdot k\right) \\ &+ \frac{1}{\alpha - 1}\left(\log(p_{t+k}) + \log(1 + r)\right). \end{aligned} \tag{5}$$

The variation in payment probabilities and interest rates identifies the utility curvature parameter α. Because the front-end delay t and back-end delay k are fixed in our CTB design, we cannot separate present bias from long-term patience using only CTB scenarios. Therefore, we use the present-bias task to separate the present-bias factor β from the discount factor δ, while simultaneously correcting for potential utility curvature α. To identify present bias, we assume that the payment c_t is received during the present, the payment $c_{t+\tau}$ marks the end of the present, and c_{t+k} is received during the future.

The subject during the present-bias task solves

$$U(800 + w_0) = \beta\delta U(c_{t+\tau} + w_{t+\tau}). \tag{6}$$

In words, the subject considers a trade-off between a direct early payment of €800 at the experimental date of end 2018 (i.e., $t = 0$), or a discounted payment $c_{t+\tau}$ one year later at the end of 2019 (i.e., $t = 1$). Solving explicitly for the present-bias factor yields

$$\beta = \frac{1}{\delta}\left(\frac{800 + w_0}{c_{t+\tau} + w_{t+\tau}}\right)^{\alpha}. \tag{7}$$

Clearly, the present-bias factor β is identified by the payment $c_{t+\tau}$, is corrected for the utility curvature α, and is separated from the long-term discount factor δ. Note that a high discount factor induces a lower present-bias factor.

Substituting the expression for β in (5), we find the following equation

$$\ln\left(\frac{c_t + w_t}{c_{t+k} + w_{t+k}}\right) = \frac{\alpha}{\alpha - 1}\log\left(\frac{800 + w_0}{c_{t+\tau} + w_{t+\tau}}\right) + \frac{1}{\alpha - 1}\log(\delta)\cdot(k-1) \\ + \frac{1}{\alpha - 1}\left(\log(p_{t+k} + \log(1+r)\right). \tag{8}$$

Given an additive error structure and assumptions on background consumption, such a linear equation is easily estimated with parameter estimates for β, δ, α obtained via nonlinear combinations of coefficient estimates. We estimate the parameters $\hat{\beta}, \hat{\delta}, \hat{\alpha}$ by two-limit tobit and, as robustness check, by OLS. To limit the number of estimated parameters and facilitate comparison with previous literature, our main results use a predetermined background income level.[15] We winsorize the estimated preference parameters at the bottom and top of the distribution for a 5% level.[16]

C. Estimated preference parameters

Table 2 presents our estimation results for the present-bias factor β, the discount factor δ and the CRRA curvature parameter α. For each individual, we estimate the preference parameters according to equations (7) and (8) and, then, we compute summary statistics for the population. We show estimation result for our complete sample, and for actives and retirees separately. We make three observations.

First, echoing the results from our descriptive analysis, we find evidence for present bias since $\beta < 1$. We estimate the median and mean present-bias factor β respectively at 0.836 and 0.819. Active pension fund participants have a lower present-bias factor than retirees, such that actives are more subject to present bias. The difference between the median present-bias factors of retirees and actives is about 0.08. Roughly 14% of our sample is future biased (i.e., $\beta > 1$). This is in line with the observation of future-biased participants in the sample of Andersen, Harrison, Lau, et al. (2014), and similar to 19% of the subjects

[15] In line with Andreoni and Sprenger (2012a) and Potters et al. (2016), we set $w_0 = w_t = w_{t+\tau} = w_{t+k} = 0.01$. We assume that subjects do not integrate the experimental payments with background income, which is a form of mental accounting: one account for the experimental payments and one for the participant's regular income.

[16] Our results below are robust to a different winsorization level, for example a level of 1%. See Table 13 in the Online Appendix.

Table 2: **Present bias, annual discounting, and curvature parameter estimates.** Two-limit tobit maximum likelihood and Ordinary Least Squares (OLS) estimates for present-bias factor β, discount factor δ, and CRRA utility curvature α.

	Median	Mean	Standard Deviation	25^{th} Percentile	75^{th} Percentile	N
Tobit: All						
Present-bias factor $\hat{\beta}$	0.836	0.819	0.184	0.695	0.953	1062
Discount factor $\hat{\delta}$	0.989	1.004	0.092	0.962	1.039	1062
Annual discount rate	0.011	0.004	0.089	-0.037	0.040	1062
CRRA curvature $\hat{\alpha}$	0.965	0.915	0.252	0.905	0.987	1062
Tobit: Actives						
Present-bias factor $\hat{\beta}$	0.820	0.802	0.185	0.672	0.938	705
Discount factor $\hat{\delta}$	0.991	1.006	0.091	0.963	1.039	705
Annual discount rate	0.009	0.001	0.086	-0.038	0.039	705
CRRA curvature $\hat{\alpha}$	0.965	0.923	0.248	0.911	0.988	705
Tobit: Retirees						
Present-bias factor $\hat{\beta}$	0.902	0.853	0.178	0.767	0.971	357
Discount factor $\hat{\delta}$	0.986	0.998	0.095	0.961	1.039	357
Annual discount rate	0.014	0.010	0.094	-0.037	0.041	357
CRRA curvature $\hat{\alpha}$	0.964	0.899	0.260	0.876	0.984	357
OLS: All						
Present-bias factor $\hat{\beta}$	0.860	0.835	0.194	0.714	0.963	1062
Discount factor $\hat{\delta}$	0.989	0.994	0.105	0.949	1.039	1062
Annual discount rate	0.011	0.018	0.111	-0.037	0.054	1062
CRRA curvature $\hat{\alpha}$	0.936	0.887	0.296	0.863	0.963	1062

being future biased in Bleichrodt et al. (2016).

A common finding in the literature is a (substantial) present bias, see for example Frederick et al. (2002), Tanaka et al. (2010), and Laibson et al. (2020). Our estimated present-bias value is similar to those estimated by other researchers. Balakrishnan et al. (2020) also use the CTB design, with also a monetary experiment, and they estimate present-bias factors between 0.902 to 0.924. Other papers have used nonmonetary experiments such as job search for estimating discounting behavior. For example, Paserman (2008) estimates a present-bias factor of 0.8937 for high income workers. DellaVigna and Paserman (2005) often find a present-bias factor near 0.9. Using experiments on real effort tasks, Augenblick, Niederle, et al. (2015) and Augenblick and Rabin (2019) find a present-bias factor ranging from 0.83 to 0.89.

Second, the estimated annual discount factor δ has a median value of 0.989 and 50% of the sample has a discount factor between 0.962 and 1.039. The annual discount factor factor translates to an annual discount rate of 1.1%.[17] About 25% of our sample has long-term negative annual discount rates, such that these participants are extremely patient as they are willing to pay, rather than generate interest, to receive a payment in the future. Differences between active participants and retirees are negligible. Our median estimated annual discount rate is in line with (long-term) market interest rates and lower than most previous studies. Estimates of annual discount rates over hundred percent are not uncommon, as shown by the overview article of Frederick et al. (2002). Cheung (2020) estimates an annual discount rate of 62.6%, when controlling for CRRA curvature. The CTB design of Andreoni and Sprenger (2012a) corrects for CRRA curvature and present bias, but they still estimate an annual discount rate of 27.5%. A close estimate is that of Andersen, Harrison, Lau, et al. (2014), who report an annual discount rate of 7.3% in the quasi-hyperbolic model, while controlling for classical risk aversion over states of the world.

A potential reason for our lower annual discount rate is the magnitude of the experimental budget and the long-term decision horizon. Thaler (1981) already shows that discount rates drop sharply as the size of wealth increases, which is known as the magnitude effect. Additionally, he reports that discount rates drop sharply as the length of time increase. We confirm both findings in our large non-student sample while controlling for risk preferences. The experimental budget of €10,000 and a decision horizon of 10 years are both (much) larger than many of the previous studies. Horizons are frequently used up to several weeks (Augenblick, Niederle, et al., 2015), 3 months (Tanaka et al., 2010), 6 months (Andersen, Harrison, M.Lauc, et al., 2010), 1 year (Dohmen, Falk, Huffman, and Sunde, 2010; Andersen, Harrison, Lau, et al., 2014), 2 years (Goda et al., 2015) and 3 years (Harrison et al., 2002). A paper that comes close to ours in terms of large stakes and long decision horizons is Potters et al. (2016). They use an experimental budget of €1,000 with a decision horizon up to

[17] The annual discount rate follows from $(1/\delta) - 1$, since the discount factor is measured in years.

retirement age and report an annual discount rate of 1%. [18]

Our third finding is that the median CRRA utility curvature α is 0.965, implying that subjects have concave utility because $\alpha < 1$. Individuals have a preference to smooth payoffs over time. A minority has a convex utility function, which implies that these individuals prefer less smoothed payoffs over time.[19]. Curvature estimates for active participants and retirees are identical at the median. Our estimated utility curvature is in line with previous CRRA curvature estimates (Andreoni and Sprenger, 2012a; Potters et al., 2016).

Notice that OLS and tobit parameter estimates are very similar for all preferences parameters. This indicates that censored corner solutions do not seem to be a major issue. Indeed, the percentage of responses that are at corners equals 46% and the number of subjects that made zero interior allocations is only 8%. Compared to the literature, these percentages are low. Andreoni and Sprenger (2012a) find that "roughly 70 percent of responses are at corners, but only 36 of 97 subjects [37%] made zero interior allocations."

Figure 5 in the Appendix summarizes the distributions visually of the present-bias factor, the annual discount factor and CRRA curvature. Clearly, there is individual heterogeneity in risk and time preferences. Due to the winsorization we observe a higher fraction of subjects at the boundaries of the distributions.

Table 8 in the Appendix shows the results of regressing the individually estimated preference parameters on personal characteristics such as demographic and financial characteristics. The main takeaway is that risk and time preferences are unaffected by self-reported life expectancy. Thus, beliefs regarding one's life expectancy are not driving our preference estimates. Note that the number of observations for this variable is low. Besides, we find that the present-bias factor correlates positively with male, age and savings. The discount factor correlates negatively with male and lower savings. The curvature parameter does not correlate with any observed individual characteristics.

Table 7 in the Appendix shows the preference parameters for the CRRA utility function formulated as $U(x) = \frac{x^{1-\gamma}}{1-\gamma}$ with $\gamma \neq 1$, where $\gamma > 0$ risk-averse behavior, $\gamma = 0$ risk-neutral

[18] Another reason might be that not all previous studies correct for utility curvature when estimating time preferences, such that discount rates might be upward biased (Andreoni and Sprenger, 2012a). However, based on high income workers, Paserman (2008) estimates a yearly discount factor of 0.9989 not corrected for curvature.

[19] CRRA curvature comes much closer to linear utility than estimates of classical risk aversion, as employed by Holt and Laury (2002) and Eckel and Grossman (2008)

behavior, and $\gamma < 0$ risk-seeking behavior. The median and mean values in Panel A show that individuals are risk averse, while time preference estimates are identical to those in Table 2. Panel B in Table 7 estimates the preference parameters when individual annual after-tax income is used as background consumption w, assuming that income w remains constant from the experimental date to future date $t + k$. The discount factor δ remains similar to the estimations without background income, but the present-bias factor β and the risk aversion parameter γ are somewhat higher.

IV. Real-life choices

This section uses administrative micro data from the pension fund to study actual annuitization decisions of retirees ($N = 357$) in relation to their individually estimated preferences. The combination of the administrative data on actual decision making with the experimental survey is a unique feature of our research. We first study how predictive preferences are for financial decision making by using a discounted expected utility model.[20] Secondly, we quantify the welfare effects of freedom of choice in annuitization decisions by studying flexibility in the payout phase of pension schemes.

A. Predictivity of annuity choices by preferences

This section studies how well risk and time preferences explain individual annuitization decisions. We use a simple discounted expected utility model in which we include the individually estimated preferences.

Utility of annuity choices

To determine the utility of annuity choices, we follow 3 steps. First, we compute the utility value of the actual observed real-life annuitization decision at retirement. Secondly, we compute the utility value of the annuity that has not been chosen. This is so to say the foregone alternative or the counterfactual. For example, if a retiree chooses a front-loaded annuity, then the foregone alternative is a flat annuity. Finally, we determine the expected

[20]Since annuity payments are no guarantee, we use the term *expected* as well.

annuity choice by comparing whether the actual or alternative annuity yields the highest utility.

If the actual chosen annuity yields higher total utility during the retirement phase than the foregone alternative annuity, then the individual made a choice in line with the model and the measured risk and time preferences. The discounted expected utility model, using the individual preferences as inputs, is able to explain actual choice behavior since the observed annuity choice coincides with the expected annuity choice. If the actual chosen annuity yields lower total utility during the retirement phase than the foregone alternative annuity, then the choice of the individual deviates from the model and the measured preferences. In this case, the discounted expected utility model suffers from a prediction error since the actual annuity choice differs from the expected annuity choice. If the difference in utility levels between the actual and expected annuity choices is large, then the prediction error is larger, and individually estimated preferences have more difficulty with explaining actual choice behavior. If the difference in utility levels between the actual and expected annuity choices is small (i.e., small prediction error), then measured preferences are not much in favor of one of the annuities.

To determine the total utility of the actual chosen annuity during the retirement phase, we compute the discounted expected utility of the annuity payments at retirement $t = 0$ by

$$U = \sum_{t=0}^{T} p(t)\phi(t; \hat{\beta}, \hat{\delta})u(x_t; \hat{\alpha}). \tag{9}$$

Thus, the annuity's utility value depends on the individually estimated risk and time preferences. $u(x_t; \hat{\alpha})$ is the CRRA utility, with estimated curvature parameter $\hat{\alpha}$, from the after-tax annuity payment x_t for $t = 0, \ldots, T$ with T the maximum time of death. $\phi(t; \hat{\beta}, \hat{\delta})$ is the individually estimated quasi-hyperbolic discount structure. Quasi-hyperbolic discounting requires a distinction between the present and the future. In line with our experimental approach and the observed front-loaded annuity characteristics, we set the present-bias interval equal to one year. So, one year after retirement consumption is valued less by an amount equal to the present-bias factor β. The model includes fund specific survival probabilities $p(t)$ at each time t, which are cohort and gender specific.[21]

[21]Since the dates of the actual annuity choice and the experiment can differ, we assume that preferences during the retirement phase remain constant. The overview study of Schildberg-Hörisch (2018) supports

To compute the utility value of the annuity that has not been chosen, we need to construct the payment scheme of the unobserved foregone alternative. To construct the payment scheme of the counterfactual, we need the individual's pension wealth at retirement. We find the individual's pension wealth by computing the present value of all future payments of the actual chosen annuity. In line with the actual fund's present value calculations, we use (i) the fund specific survival probabilities $p(t)$ for every date, cohort and gender, and (ii) an actuarial interest rate of 1.39% to discount future payments, as set by the Dutch Central Bank in 2018 based on the yield curve.[22] Ultimately, we convert the individual's pension wealth into the unchosen foregone annuity.

If the retiree actually chooses a front-loaded annuity, then for the counterfactual we convert pension wealth into the default flat annuity. We assume that the flat annuity starts at the observed date of retirement. For example, in case of early retirement, the retiree still retires early, but she receives a flat life-long annuity rather than her chosen front-loaded life-long annuity. If the retiree actually chooses a flat annuity, then for the counterfactual we convert pension wealth into a front-loaded annuity. Again, we assume that the front-loaded payments start at the observed date of retirement. In line with our earlier observations regarding pension choices, we assume that front-loaded annuities start with high payments at retirement for a duration of 3 years, and low payments are equal to the legal minimum of 75% of the high payments.

Observed and expected annuity choices

We now study the relation between preferences, observed annuity choices and expected annuity choices. We distinguish between four groups, because the observed annuity choice can be in line with the expected annuity choice, or not: "actual flat, expected front-loaded", "actual front-loaded, expected front-loaded", "actual front-loaded, expected flat", and "actual flat, expected flat".

Table 3 shows the relation between annuity choices and median measured preferences. First, we discuss the relation between preferences and expected annuity choices, then we include the actual annuity choices. We observe that an expected front-loaded annuity is accompanied by a lower median discount factor δ and a higher median curvature parameter

this claim for risk preferences for example.

[22] We do not use the self-reported life-expectancies as the number of observations would become too low.

Table 3: **Annuity choices, preferences, and welfare effects** This table presents the median present-bias factor $\hat{\beta}$, the median long-run discount factor $\hat{\delta}$, and the median curvature parameter $\hat{\alpha}$ for the actual and expected annuity choices according to the observed preferences. Between parentheses the mean time preference parameter values. Potential and realized welfare effects, associated with actual and expected annuity choices, are shown in the last two columns.

	Observed preferences			Welfare effects	
	$\hat{\beta}$	$\hat{\delta}$	$\hat{\alpha}$	Potential	Realized
1. Actual **flat**, expected **front-loaded**	0.94	0.96	0.97	+	0
	(0.91)	(0.94)	(0.89)		
2. Actual **front-loaded**, expected **front-loaded**	0.93	0.96	0.95	+	+
	(0.91)	(0.95)	(0.88)		
3. Actual **front-loaded**, expected **flat**	0.87	1.01	0.96		-
	(0.84)	(1.02)	(0.88)		
4. Actual **flat**, expected **flat**	0.82	1.03	0.96		
	(0.79)	(1.05)	(0.92)		

α relative to an expected flat annuity. Namely, a lower discount factor δ implies stronger long-run impatience, while a higher curvature parameter α implies a preference for a less smoothed consumption path. A front-loaded annuity therefore fits individuals with stronger impatience, and a front-loaded annuity is also less smooth than a flat annuity. On the other hand, an expected flat annuity is accompanied by a median discount factor close to one. Individuals that are expected to choose a flat annuity are individuals with a preference for smooth consumption paths and they are more patient than individuals that prefer a front-loaded annuity.

From the perspective of actual annuity choices, we see that the group "actual front-loaded, expected flat" has a relatively low median present-bias factor. These individuals are relatively present biased and, thus, tempted to actually choose front-loaded annuity payments. The group "actual front-loaded, expected front-loaded" has similar preferences to the group "actual flat, expected front-loaded". Note that the group "actual flat, expected flat" has a low median present-bias factor as well, however the relatively high median long-term discount factor and the relatively low median curvature parameter are dominating for this group. The discount factor and curvature parameter matter for each year in the utility calculations, while the present-bias factor only matters the first few years. Because the median discount factor is relatively high, the median present-bias factor is lower due to the experimental answers and the estimation methodology, as shown in the expression for β in equation (7).

Table 4, Panel A, shows the number of individuals for the actual observed annuity choices and the expected annuity choices. The total sample of retirees is $N = 357$. 248 retirees actually choose a flat annuity, while 109 retirees actually choose a front-loaded annuity. A potential reason for this difference is that the pension fund offers the flat annuity as a default. Based on the individually estimated preferences, the discounted expected utility model expects that 195 retirees choose a flat annuity and 162 retirees choose a front-loaded annuity. Thus, we observe that too many individuals actually choose a flat annuity compared to their expected choice based on individually estimated preferences. For 52% of the retirees (i.e., 184 retirees out of 357, of which 135 choosing flat and 49 choosing front-loaded) the individually estimated preferences explain actual annuity choices according to the expected annuity choices based on the discounted expected utility model. However, asking our simplified model to explain annuity choices with perfect utility indifference might be too strict, so we study the utility differences between actual and expected annuity choices in the case annuities might be perceived as observationally equivalent.

Indifference bandwidths

We now allow for the possibility that expected annuity choices lie within an indifference bandwidth of the actual annuity choices.[23] Within this bandwidth, we argue that actual and expected annuity choices are observationally equivalent for the individual in terms of utility.

We compute the bounds of the indifference bands by the difference between the actual (x_t^{act}) and expected (x_t^{exp}) annuity payments. The bound of the bandwidth determines the maximum allowed utility difference between the actual and expected annuity choice to be observationally equivalent. The bound of the bandwidth ε is defined as the annual percentage consumption loss and determined by

$$\sum_{t=0}^{T} p(t)\phi(t;\hat{\beta},\hat{\delta})u\left(x_t^{act}\cdot(1+\varepsilon);\hat{\alpha}\right) = \sum_{t=0}^{T} p(t)\phi(t;\hat{\beta},\hat{\delta})u\left(x_t^{exp};\hat{\alpha}\right). \tag{10}$$

If the bound of the indifference bandwidth ε is zero or negative, then the discounted expected utility model — with individual preferences as inputs — explains the actual choice

[23] One interpretation is that preferences might be measured with some error or the discounted expected utility model might be misspecified.

Table 4: **Explanatory power of preferences for annuity choices.** In Panel A, the observed preferences show the actual annuity choices against the expected utility choices, according to the individually estimated risk and time preferences. The long-run preferences show the actual annuity choices against the expected-utility choices according to the individually estimated risk and time preferences under the persistent long-run view, i.e., present-bias factor $\hat{\beta}_i = 1$ for each retiree i. Panel B, based on observed preferences, shows the actual annuity choices against the expected utility choices for several utility indifference bandwidths.

Panel A: No utility indifference					
		Observed preferences			
			Actual		
			Flat	Front-loaded	Total
	Expected	Flat	135	60	195
		Front-loaded	113	49	162
		Total	248	109	357
		Long-run preferences			
			Actual		
			Flat	Front-loaded	Total
	Expected	Flat	142	64	206
		Front-loaded	106	45	151
		Total	248	109	357
Panel B: Utility indifference bandwidths					
			Actual		
			Flat	Front-loaded	Total
Annual cons. difference ≤ 0.01	Expected	Flat	180	35	215
		Front-loaded	68	74	142
		Total	248	109	357
			Actual		
			Flat	Front-loaded	Total
Annual cons. difference ≤ 0.02	Expected	Flat	206	21	227
		Front-loaded	42	88	130
		Total	248	109	357
			Actual		
			Flat	Front-loaded	Total
Annual cons. difference ≤ 0.03	Expected	Flat	222	14	236
		Front-loaded	26	95	121
		Total	248	109	357
			Actual		
			Flat	Front-loaded	Total
Annual cons. difference ≤ 0.04	Expected	Flat	232	11	243
		Front-loaded	16	98	114
		Total	248	109	357
			Actual		
			Flat	Front-loaded	Total
Annual cons. difference ≤ 0.05	Expected	Flat	236	6	242
		Front-loaded	12	103	115
		Total	248	109	357

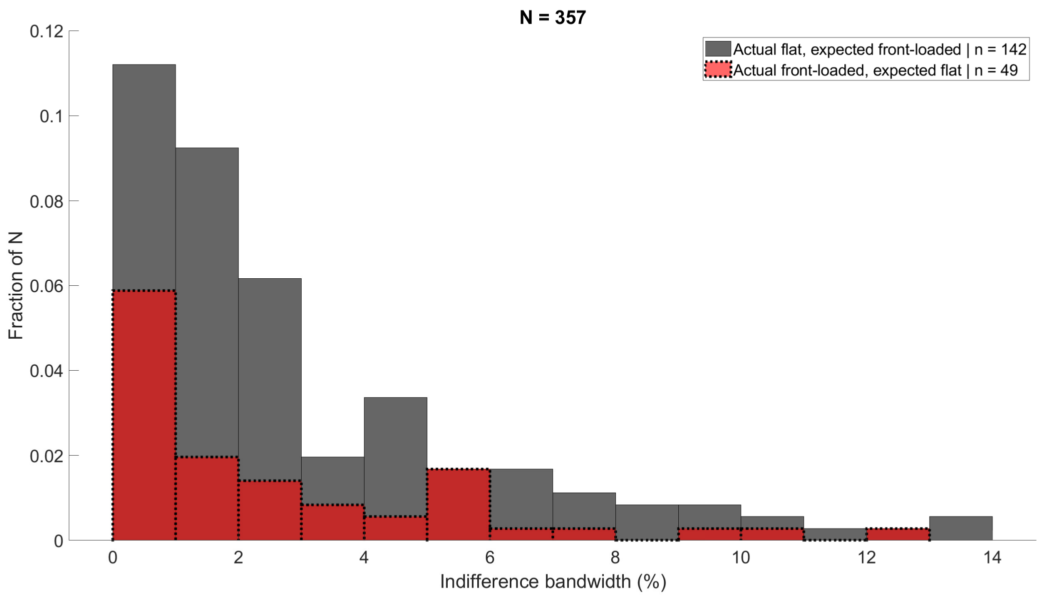
of the retiree entirely successful. Namely, the actual annuity choice yields equal utility or higher utility than the expected utility choice. Thus, the individual makes an actual annuity choice that maximizes her utility given her preferences. In Table 4, this holds true for the 52% of our sample, namely 184 retirees out of the 357 (i.e., the retirees on the diagonal).

If the bound of the indifference bandwidth is not too large and positive, i.e., $\varepsilon > 0$, then actual and expected annuity choices are observationally equivalent for the individual as utility differences are small. Stated differently, individual preferences explain the actual choice of the retiree with some prediction error. The severity of misprediction is given by the magnitude ε in terms of annual certainty equivalent consumption. In case the indifference interval is not too wide, then individually estimated preferences explain actual choices. In Table 4, the groups "actual flat, expected front-loaded" and "actual front-loaded, expected flat" suffer from some prediction error. We now study the severity of these predictions error and the indifference bandwidths.

Table 4, Panel B, presents the number of retirees for each indifference bandwidth ε. We create indifference bandwidths from 0% to 5% annual consumption loss. Panel B shows that individually estimated preferences explain actual annuity choices for 82% of the retirees if the indifference bandwidth is at most 2% annual consumption loss (i.e., 206+88 retirees out of 357). The explanatory power of individually estimated preferences is 82% when the indifference bandwidth equals at most 2% annual consumption loss. Or, the other way around, the percentage of cases with a severe prediction error, e.g., larger than 2%, is only 18%. Of course, if the indifference bandwidth becomes larger, then individually estimated preferences explain actual annuity choices to a larger extent.

Figure 4 shows the distribution of explained annuity choices for each indifference interval, excluding the correct predictions $\varepsilon = 0$. Stated differently, we display the distribution of explained annuity choices for the groups "actual flat, expected front-loaded" and "actual front-loaded, expected flat". The fraction of explained annuity choices clusters mainly around zero or close to zero, which supports the idea that risk and time preferences explain financial decision making. The severity of prediction errors is distributed similarly amongst both groups.

Figure 4: **Distribution of explained annuity choices.** The figure displays the fraction of explained annuity choices by individually estimated preferences for each indifference bandwidths. The distribution excludes the group with a prediction error of zero, i.e., $\varepsilon = 0$.



B. Welfare effects

Given that individually estimated preferences are able to explain annuity choices, we study in this final section the welfare effects of front-loaded annuity. The option to take a front-loaded annuity creates freedom of choice. Freedom of choice may generate welfare gains, but also welfare losses. Specifically, front-loaded annuity cause potential and realized welfare gains and losses. This section computes the potential and realized welfare effects of freedom of choice in annuitization decisions.

To evaluate the policy of freedom of choice in annuitization decisions, a welfare criterion is needed. A common choice to evaluate welfare is from a long-run perspective, on the grounds that these are the preferences that are persistent (Ericson and Laibson, 2019). In line with Ericson and Laibson (2019), this implies that we study choice behavior if individuals are dynamically consistent, i.e., retirees do not suffer from present bias. So, for each individual we set the estimated present-bias factor $\hat{\beta} = 1$. Using the discounted expected utility model in equation (9) we compute the actual and expected annuities' utility values.

Table 4, Panel A, shows the actual observed annuity choice and the expected annuity choice from a long-run welfare perspective, i.e., setting $\hat{\beta} = 1$. Of course, the actual observed annuity choices are identical to the "observed preferences": 248 retirees actually choose flat, while 109 retirees choose a front-loaded annuity. According to the long-run preferences (i.e., $\hat{\beta} = 1$), it is expected that 206 retirees choose a flat annuity and 151 retirees choose a front-loaded annuity. Compared to the "observed preferences", the expected utility model using "long-run preferences" predicts that a higher number of retirees prefers a flat annuity, while a lower number of retirees prefers a front-loaded annuity. This is intuitive, because not being subject to present bias pulls individuals away from the possibly tempting choice of a front-loaded annuity. Still, we observe that relatively too many individuals choose actually a flat annuity compared to their expected annuity choices, which may be due to the flat annuity being the default.

Potential and realized welfare effects

To analyse the welfare effects of the option to choose a front-loaded annuity, we distinguish between potential and realized welfare effects. Furthermore, we split these welfare effects in gains (+), losses (-) and no effect (0). Table 3 summarizes our explanations below.

The potential welfare gains (+) from a front-loaded annuity come from individuals that are expected to choose a front-loaded annuity, based on their long-run preferences. Namely, from a long-run welfare perspective (i.e., $\hat{\beta} = 1$), it increases the total utility of these retirees to choose a front-loaded annuity. Thus, potential welfare gains of a front-loaded annuity come from the groups "actual flat, expected front-loaded" and "actual front-loaded, expected front-loaded". As Table 3 confirms, the long-run discount factors are the lowest among these 2 groups, indicating that these retirees are the most impatient in the long run and prefer front-loaded annuities. Potential welfare effects are defined as the sum of these two groups.

Realized welfare effects are defined as the sum of realized gains (+), losses (-), and no effects (0). Realized welfare gains (+) from a front-loaded annuity come from individuals that are expected to choose a front-loaded annuity and actually do so. Stated differently, the group "actual front-loaded, expected front-loaded" chooses their actual annuity in line with their long-run preferences. Realized welfare losses (-) from the option to take a front-loaded annuity stem from individuals that actually choose a front-loaded annuity, but are expected to choose a flat annuity given their long-run preferences. The main mechanism here is that the group "actual front-loaded, expected flat" chooses a front-loaded annuity because the present-bias factor is relatively low (i.e., 0.87 at the median), while from a long-run perspective this group is patient as the long-run discount factor is close to one (i.e., 1.01 at the median). The group "actual flat, expected front-loaded" has no effect (0) on the realized welfare of a front-loaded annuity, as these individuals realized a flat annuity and, therefore, the potential welfare is unrealized. Finally, we leave the group "actual flat, expected flat" outside the welfare analysis because it has no implications for the welfare effects of a front-loaded annuity.

To determine the magnitude of the welfare effects, we calculate the annual percentage consumption effect ε using equation (10) with $\hat{\beta} = 1$. For the group "actual flat, expected front-loaded", the potential welfare gain follows naturally from equation (10) as ε is positive since the expected choice always yields equal or higher utility than the actual choice. For the group "actual front-loaded, expected flat", the realized welfare loss follows from equation (10) by converting the positive ε to its negative counterpart. Namely, we want to know the consumption loss that occurs by foregoing to choose a flat annuity. For the group "actual front-loaded, expected front-loaded", we compute the potential and realized welfare gains as follows. We counterfactually assume as if this group actually chooses a flat annuity. Then, we quantify the potential and realized consumption gains by directly computing ε in equation (10). Again, the potential and realized welfare gains follow naturally from equation (10) as ε is positive since the expected choice always yields equal or higher utility than the actual choice, such that these positive values indicate the annual percentage consumption gains of a front-loaded annuity.

Table 5: **Potential and realized welfare gains and losses due to freedom of choice.** This table presents the annual consumption effects (CE) in percentage (%) and the monetary welfare effects in Euro (€) for each indifference interval.

	Indifference interval (%)													
	0		[0,1]		[0,2]		[0,3]		[0,4]		[0,5]		[0,∞)	
	CE	€	CE	€	CE	€	CE	€	CE	€	CE	€	CE	€
Panel A: Potential welfare														
Mean	2.77	13417	1.66	7969	1.61	7659	1.74	8160	1.87	8993	1.94	9355	2.29	11599
Median	1.89	7624	0.63	2884	0.95	4195	1.18	5100	1.32	5790	1.37	5895	1.63	6974
Std. Dev.	3.12	14919	2.59	12487	2.27	11012	2.15	10454	2.12	10607	2.12	10683	2.38	13392
5% perc.	0.13	324	0.03	93	0.04	112	0.04	117	0.04	120	0.04	121	0.04	124
95% perc.	10.70	41982	6.31	38092	6.17	33674	5.99	31877	5.79	30549	5.68	29911	6.18	37613
Percentage population	24	24	33	33	37	37	39	39	41	41	41	41	42	42
Observations pot. welfare	45	45	83	83	109	109	125	125	135	135	139	139	151	151
Observations interval	191	191	254	254	294	294	317	317	330	330	339	339	357	357
Panel B: Realized welfare														
Mean	2.50	12141	0.98	4715	0.56	2586	0.39	1771	0.31	1358	0.17	663	-0.07	-262
Median	1.81	7114	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Std. Dev.	3.12	14928	2.47	11892	2.27	11110	2.20	10796	2.18	10736	2.28	11334	2.63	12136
5% perc.	-0.55	-2301	-0.78	-4588	-1.63	-10395	-2.06	-11718	-2.40	-11994	-2.67	-14306	-4.33	-18655
95% perc.	10.35	41379	6.15	33251	5.31	28019	4.82	26254	4.72	24807	4.56	23998	4.17	22852
Percentage population	26	26	44	44	52	52	55	55	57	57	58	58	60	60
Observations real. welfare	49	49	112	112	152	152	175	175	188	188	197	197	215	215
Observations interval	191	191	254	254	294	294	317	317	330	330	339	339	357	357
Panel C: Potential welfare for population														
Mean	0.65	3161	0.54	2604	0.60	2840	0.69	3218	0.77	3679	0.80	3836	0.97	4906
Median	0.45	1796	0.21	943	0.35	1555	0.46	2011	0.54	2369	0.56	2417	0.69	2950
Std. Dev.	0.73	3515	0.85	4080	0.84	4083	0.85	4122	0.87	4339	0.87	4381	1.01	5664
5% perc.	0.03	76	0.01	31	0.01	41	0.02	46	0.02	49	0.02	49	0.02	53
95% perc.	2.52	9891	2.06	12447	2.29	12484	2.36	12570	2.37	12498	2.33	12264	2.62	15909
Panel D: Realized welfare for population														
Mean	0.64	3115	0.43	2079	0.29	1337	0.22	978	0.18	774	0.10	385	-0.04	-158
Median	0.46	1825	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Std. Dev.	0.80	3830	1.09	5244	1.17	5744	1.21	5960	1.24	6116	1.32	6587	1.58	7309
5% perc.	-0.14	-590	-0.34	-2023	-0.85	-5374	-1.14	-6469	-1.37	-6833	-1.55	-8314	-2.61	-11235
95% perc.	2.66	10615	2.71	14662	2.75	14486	2.66	14493	2.69	14133	2.65	13946	2.51	13763

Table 5 presents an overview of the potential and realized welfare effects. We compute the welfare effects for different subsamples. Namely, we want to assure that preferences have predictive power for annuity choices when doing a welfare analysis. The smaller the interval, the more strict the individual determines indifference between her actual and expected annuity choice. Panels A and B display the conditional potential and realized welfare effects, i.e., only for the affecting the potential and realized welfare. Panels C and D display the unconditional potential and realized welfare effects, i.e., including the group of retirees "actual flat, expected flat". We do the latter, because welfare effects can be substantial for a small number of affected individuals, but smoothed over the other individuals in society, welfare effects might appear differently. Besides the effects on annual percentage consumption, we also compute the monetary welfare effects in terms of additional present value pension wealth at retirement.

For an indifference bandwidth of 2%, the mean potential welfare effect of a front-loaded annuity is a gain of 1.61%.[24] Unconditional potential welfare in Panel C yields an average potential welfare gain of 0.60%. Realized welfare gains are lower, but still positive on average: 0.56% for the conditional sample (Panel B), and on average 0.29% for the unconditional sample (Panel C). In terms of money, Panels A (C) and B (D) show that the average individual has a potential gain of €7659 (€2840), but only realizes €2586 (€1337). The 5%-percentile shows that realized welfare is negative. Welfare effects are similar for other indifference intervals, where the highest average potential welfare of 2.77% is attained in the indifference interval with zero prediction error. Hence, a takeaway is that policy making can be improved to guide individuals in annuitization decisions, because there is still unrealized welfare in the economy.

V. Conclusion

To the best of our knowledge, our paper is the first to relate domain specific and simultaneously measured risk and time preferences to real-life annuitization decisions through a utility framework rather than measuring general preferences and stated behavior related via separate correlations. We simultaneously measure risk and time preferences in a real-life

[24]The number is based on 83 observations from the groups "actual flat, expected front-loaded" and "actual front-loaded" as a fraction of the total number of 294 retirees in the indifference interval.

pension context, with long horizons, for a large group of pension fund participants. We base our method on the Convex Time Budgets of Andreoni and Sprenger (2012a) with an additional present-bias task (Rieger et al., 2015; Wang, 2017). We use the individually estimated preferences as inputs in a discounted expected utility framework to predict actual observed annuity decisions. Given the predictive power of preferences for actual annuity choices, we quantify the welfare effects of freedom of choice in the annuitization decision between a flat and front-loaded annuity.

We find that pension fund participants are present biased, but retirees are less present biased than active participants. In the context of pension decision making, involving long horizons and large stakes, we find annual discount rates close to 1% and utility curvature close to unity. The front-loaded annuity from the Dutch pension fund, replicating characteristics of a lump sum, is actually chosen over a flat annuity by present biased individuals, while those individuals act patient in the long run. The discounted expected utility model, with measured preferences as inputs, explains for 82% of the retirees actual annuitization decisions for an indifference bandwidth of at most 2%. Within this bandwidth, we argue that the actual and utility-expected annuity choices are observationally equivalent for the individual in terms of utility. For an indifference interval of 2%, conditional individual potential welfare gains are on average 1.61% (€7659) but only 0.56% (€2586) is realized and welfare losses even realize at the lower end of the distribution.

Our study is based on a unique dataset of individual decisions made with regard to the Dutch second pillar. We augment the dataset by survey data, which includes our experiments on risk and time preferences. The measurement of preferences in the same domain, context, and population as the actual decision making is a novel feature of our research. The data deals with real annuity choices rather than self-reported intentions. Our analysis is based on administrative records of the Dutch pension fund, including fund specific survival probabilities. The Dutch case is interesting as occupational pensions are very common and the pension choices involve large amounts of money.

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Appendix

Figure 5: **Distributions of estimated individual present-bias factor, annual discount factor and CRRA curvature.** These distributions are based on the estimated parameters from Table 2.

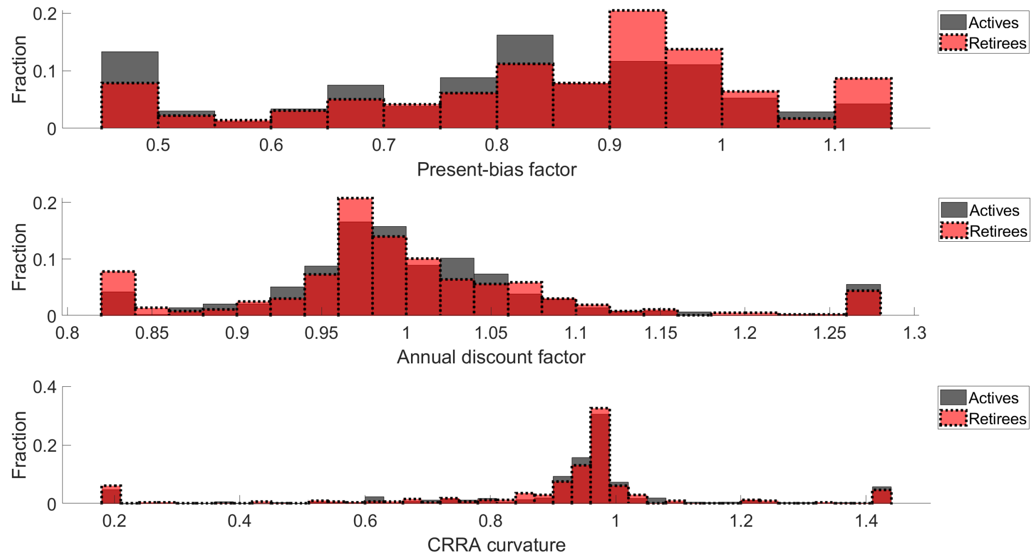

Table 6: **Overview experimental design: Convex Time Budgets and present bias.** Choice sets in the Convex Time Budgets and present-bias task. t and k are front and end delays in years, and c_t and c_{t+k} are allocated amounts in Euros. $1 + r$ is the implied gross interest rates. Annual r is the yearly interest rate in percent and calculated as $((1 + r)^{1/k} - 1) \times 100$. For the present bias task subjects enter an amount (in €) for $c_{t+\tau}$.

Task	Scenario	Set	t	k	p_{t+k}	c_t	c_{t+k}	$1+r$	Annual r
Convex Time Budgets	1	1	1	10	0.5	10,000	14,100	1.41	3.50
	2	1	1	10	0.5	10,000	14,900	1.49	4.07
	3	1	1	10	0.5	10,000	16,600	1.66	5.20
	4	1	1	10	0.5	10,000	19,300	1.93	6.80
	5	1	1	10	0.5	10,000	22,400	2.24	8.40
	6	2	1	10	0.7	10,000	12,000	1.20	1.84
	7	2	1	10	0.7	10,000	12,600	1.26	2.34
	8	2	1	10	0.7	10,000	14,000	1.40	3.42
	9	2	1	10	0.7	10,000	16,300	1.63	5.01
	10	2	1	10	0.7	10,000	19,000	1.90	6.63
	11	3	1	10	0.9	10,000	10,500	1.05	0.49
	12	3	1	10	0.9	10,000	11,100	1.11	1.05
	13	3	1	10	0.9	10,000	12,300	1.23	2.09
	14	3	1	10	0.9	10,000	14,400	1.44	3.71
	15	3	1	10	0.9	10,000	16,700	1.67	5.26
	16	4	1	10	1.0	10,000	10,000	1.00	0.00
	17	4	1	10	1.0	10,000	10,500	1.05	0.49
	18	4	1	10	1.0	10,000	11,700	1.17	1.58
	19	4	1	10	1.0	10,000	13,600	1.36	3.12
	20	4	1	10	1.0	10,000	15,900	1.59	4.75
Present bias	21	5	0	1	1.0	800	$c_{t+\tau}$	$800/c_{t+\tau}$	$800/c_{t+\tau} - 1$

Table 7: **Individual present bias, annual discounting and risk aversion parameter estimates.** Two-limit tobit maximum likelihood estimates for CRRA risk aversion γ, present-bias factor β, and discount factor δ. The CRRA utility function is $x^{(1-\gamma)}/(1-\gamma)$ for $\gamma \neq 1$: $\gamma = 0$ denotes risk neutral behavior, $\gamma > 0$ denotes risk aversion and $\gamma < 0$ denotes risk seeking behavior. Panel A presents estimation results without background income, i.e., $w = 0$. Panel B presents the preference parameters when individual annual after-tax income is used in the estimation.

	Median	Mean	Standard Deviation	25^{th} Percentile	75^{th} Percentile	N
Panel A: Without background income						
Present-bias factor $\hat{\beta}$	0.836	0.819	0.184	0.695	0.953	1062
Discount factor $\hat{\delta}$	0.989	1.004	0.092	0.962	1.039	1062
Annual discount rate	0.011	0.004	0.089	-0.037	0.040	1062
CRRA risk aversion $\hat{\gamma}$	0.035	0.085	0.252	0.013	0.095	1062
Panel B: With background income						
Present-bias factor $\hat{\beta}$	1.025	1.021	0.103	0.978	1.058	1000
Discount factor $\hat{\delta}$	0.975	0.998	0.114	0.950	1.029	1000
Annual discount rate	0.025	0.014	0.105	-0.028	0.052	1000
CRRA risk aversion $\hat{\gamma}$	1.430	1.911	4.724	0.587	3.028	1000

Table 8: **Preferences and personal characteristics**. The table presents correlations of three Ordinary Least Squares (OLS) regressions with the individually estimated preferences as dependent variables: present-bias factor $\hat{\beta}$, discount factor $\hat{\delta}$, and curvature $\hat{\alpha}$. Controls include the duration and reported complexity of the survey. ** and * indicate statistical significance at the 5% and 10% level, respectively. Robust standard errors (MacKinnon and White, 1985) between parentheses.

	Present-bias factor		Discount factor		Curvature	
Male	0.029**		-0.016**		0.014	
	(0.015)		(0.007)		(0.02)	
Age	0.003**		0		-0.002	
	(0.001)		(0.001)		(0.002)	
Edu. medium	-0.034		-0.023		0.02	
	(0.042)		(0.031)		(0.09)	
Edu high	0.009		-0.038		0.042	
	(0.04)		(0.031)		(0.088)	
Partner	-0.009		0.007		0.003	
	(0.016)		(0.008)		(0.023)	
Income ($\times$1000)	-0.001		0.001		0.004	
	(0.004)		(0.002)		(0.006)	
Savings 5k-10k	0.053**		-0.022*		0.014	
	(0.023)		(0.012)		(0.033)	
Savings 10k-30k	0.056**		-0.018*		-0.028	
	(0.02)		(0.01)		(0.027)	
Savings 30k-50k	0.062**		-0.011		-0.028	
	(0.022)		(0.011)		(0.03)	
Savings $\geq$ 50k	0.091**		-0.014		-0.011	
	(0.02)		(0.01)		(0.028)	
Life expectancy		0.004*		0		-0.001
		(0.002)		(0.001)		(0.003)
Constant	0.55**	0.457**	1.061**	0.995**	0.953**	0.991**
	(0.085)	(0.199)	(0.051)	(0.086)	(0.14)	(0.22)
Observations	862	395	862	395	862	395
Controls	Yes	No	Yes	No	Yes	No

Online appendix

Estimation

There are N experimental subjects and P convex budget decisions, where we combine the present-bias task with the CTB decisions. We assume that each subject j makes her allocation decision $c_{t_{i,j}}$, $i = 1, ..., P$, according to the relationship in (5), but that each decision is made with some additive mean-zero (potentially correlated) error. That is,

$$\ln\left(\frac{c_t + w_t}{c_{t+k} + w_{t+k}}\right)_{i,j} = \frac{1}{\alpha - 1}\left(\log(\beta)\cdot \mathbb{1}_{t\in[0,1]} + \log(\delta)\cdot k\right) + \frac{1}{\alpha - 1}\left(\log(p_{t+k_i}) + \log(1 + r_i)\right) + \varepsilon_{i,j}. \tag{11}$$

Stacking the P observations per individual j, we have

$$\ln\left(\frac{\boldsymbol{c_t} + \boldsymbol{w_t}}{\boldsymbol{c_{t+k}} + \boldsymbol{w_{t+k}}}\right)_{\boldsymbol{j}} = \frac{1}{\alpha - 1}\left(\log(\beta)\cdot \mathbb{1}_{t\in[0,1]} + \log(\delta)\cdot k\right) + \frac{1}{\alpha - 1}\left(\log(\boldsymbol{p_{t+k}}) + \log(\boldsymbol{1} + \boldsymbol{r})\right) + \boldsymbol{\varepsilon_j}. \tag{12}$$

The vector $\boldsymbol{\varepsilon_j}$ is zero in expectation with variance-covariance matrix $\boldsymbol{\Sigma_j}$, a $P \times P$ matrix, allowing for arbitrary correlation in the errors $\varepsilon_{i,j}$. For each subject j, we assume that all decisions i are subject to an error with mean zero and variance σ_i^2. So, $\boldsymbol{\Sigma_j}$ is a (homogeneous) diagonal variance-covariance matrix with entries σ_i^2 on the diagonal and zeros off diagonal. In other words, the error term is the same within subject j for each decision i, but the error term may vary across individuals.

Equation (12) is easily estimated with ordinary least squares. However, the log-consumption ratio is censored by the corner responses on the budget constraint

$$\ln\left(\frac{\boldsymbol{c_t} + \boldsymbol{w_t}}{\boldsymbol{c_{t+k}} + \boldsymbol{w_{t+k}}}\right)_{\boldsymbol{j}} \in \left(\ln\left(\frac{\boldsymbol{0} + \boldsymbol{w_t}}{(\boldsymbol{m}\cdot(\boldsymbol{1}+\boldsymbol{r})) + \boldsymbol{w_{t+k}}}\right)_{\boldsymbol{j}}, \ln\left(\frac{\boldsymbol{m} + \boldsymbol{w_t}}{\boldsymbol{0} + \boldsymbol{w_{t+k}}}\right)_{\boldsymbol{j}}\right). \tag{13}$$

Namely, either the subject allocates the complete budget m to the late payment at the vector of gross interest rates $\boldsymbol{1} + \boldsymbol{r}$ (and allocates nothing to the early payment), or the subject allocates the complete budget m to the early payment (and allocates nothing to the late payment). These corner solutions motivate the use of censored regression techniques such as the two-limit tobit model.

Finally, the risk- and time-preference parameters for each individual j can be estimated via the linear equation

$$\ln\left(\frac{\boldsymbol{c_t}+\boldsymbol{w_t}}{\boldsymbol{c_{t+k}}+\boldsymbol{w_{t+k}}}\right)_{\boldsymbol{j}} = \eta_{j,0} + \eta_{j,1}\cdot(\ln(\mathbf{1}+\boldsymbol{r}) + \ln(\boldsymbol{p_{t+k}})) + \boldsymbol{\varepsilon_j}, \tag{14}$$

where $\eta_{j,0}$ and $\eta_{j,1}$ are the individual specific intercept and regression coefficient, respectively. For each individual j, the preference estimates for utility curvature, long-term discounting and present bias are found via the non-linear combinations

$$\begin{aligned}
\hat{\alpha} &= \frac{1}{\hat{\eta_{j,1}}} + 1,\\
\hat{\delta} &= \exp\left[\frac{\hat{\alpha}-1}{k-1}\left(\hat{\eta}_{j,0} - \frac{\hat{\alpha}}{\hat{\alpha}-1}\log\left(\frac{800+w_0}{c_{t+\tau}+w_{t+\tau}}\right)\right)\right],\\
\hat{\beta} &= \frac{1}{\hat{\delta}}\left(\frac{800+w_0}{c_{t+\tau}+w_{t+\tau}}\right)^{\hat{\alpha}}.
\end{aligned} \tag{15}$$

A point of attention is that the background consumption parameters are known or fixed and, secondly, that the consumption ratio $(c_t + w_t)/(c_{t+k} + w_{t+k})_{i,j}$ is strictly positive, such that the log transform is well-defined. The strength is that corner solutions are easily addressed by censoring models such as two-limit tobit maximum likelihood regression.

Additional summary statistics and tax levels

Robustness check

Table 9: **Additional summary statistics of the sample.**

	Mean	Median	Standard Deviation	N
Panel A: Demographics				
Male	0.57	1.00	0.50	1062
Age (years)	60.45	60.60	5.89	1062
Education (classes)	3.90	4.00	0.97	1058
Retired	0.34	0.00	0.47	1062
Partner	0.82	1.00	0.39	1055
Children	1.83	2.00	1.23	1058
Panel B: Financial				
Income	53119	51329	22451	1000
Savings	49198	20000	80970	945
Homeowner	0.90	1.00	0.29	1059
Plan to buy	0.13	0.00	0.34	85
Rent price	744	693	282	74
House price	300750	269000	244620	893
Mortgage	0.82	1.00	0.38	947
Expect inheritance	0.26	0.00	0.44	979
Inheritance amount	88393	56250	113280	224
Leave bequest	0.58	1.00	0.49	755
Bequest amount	151020	150000	145730	343
Panel C: Pension				
Pension income	22546	20916	13735	1000
Pension income (max)	29357	28463	15243	1000
Other pension income	7466	500	16548	280
Individual pension income	50000	30000	41569	22
Part-time pension	0.00	0.00	0.00	357
AOW bridge	0.40	0.00	0.49	357
Flexible pension	0.35	0.00	0.48	357
Transfer partner pension	0.23	0.00	0.42	357
Intended retirement year	-2.58	-3.00	2.21	627
Attitude pension choice	4.43	5.00	0.75	1060
Attitude premium stop	2.64	3.00	1.04	1036
Attitude flexible pension age	4.50	5.00	0.70	1056
Attitude flexible pension benefits	3.81	4.00	1.07	1050
Panel D: Other				
Life expectancy	84.01	85.00	4.29	395
Duration (min.)	311.71	19.78	1728.70	1062
Complexity	2.86	3.00	1.01	1028

Table 10: **Definition of variables.** [a] Participants could easily access this information via a provided link directing to house price administration

Variable	Definition
	Panel A: Demographics
Male	Dummy; 1 = male; 0 = female
Age	Age in years (pension fund administration)
Education	Classes; 0 = primary school; 1 = secondary school; 2 = pre-vocational education and training (LBO); 3 = vocational education and training (MBO); 4 = university of applied sciences (HBO); 5 = university
Retired	Dummy; 1 = retired participant (retiree); 0 = active participant (worker)
Partner	Dummy; 1 = married, registered partnership or cohabitation; 0 = no partner
Children	Number of children
	Panel B: Financial
Income	Individual annual before tax income. For retirees, all employer-related second pillar pension benefits received from the pension fund including state pension benefits. For workers, salary corrected for part-time work.
Private savings	Self-reported total individual amount of voluntary liquid savings (e.g. a bank account and/or investments) in one of the classes: (0-5,000), (5,001-10,001),(10,001-30,000), (30,001-50,000), (50,001-100,000), (100,001-200,000), (200,001-400,000), (> 400,000). Excluding house and pension savings.
Homeowner	Dummy; 1 = House owner, 0 = rent a house
Plan to buy	Dummy; 1 = Rent a house, but planning to buy a house, 0 = rent a house, but not planning to buy a house
Rent price	Self-reported current rent price of house (on household level) for tenants (including service fees, excluding gas, water and electricity costs)
House price	Self-reported current house price (on household level) for homeowners; 0 = renting a house[a]
Mortgage	Dummy; 1 = currently one or more mortgage loans; 0 = currently no mortgage loans
Expect inheritance	Dummy; 1 = expect to receive an inheritance (money, real estate or other possessions) during remaining life cycle; 0 = no
Inheritance amount	Individual expected inherited amount in one of the classes: (< 25,000), (25,001-50,000), (50,001-100,000), (100,001-300,000), (300,001-500,000), (> 500,000)
Leave bequest	Dummy; 1 = wish to leave a bequest (savings, house or other possessions) when passing away; 0 = no
Bequest amount	Individual expected bequest amount in one the classes: (< 25,000), (25,001-50,000), (50,001-100,000), (100,001-300,000), (300,001-500,000), (> 500,000)

Table 11: **Definition of variables (continued).** Att. is abbreviation for attitude, and AOW is abbreviation for state pension. [a] Participants could easily access this information via a provided link directing to the pension government administration. [b] Participants were provided that per year of early retirement pension benefits decrease by 6%, and per year of later retirement pension benefits increase by 8%. [c] Participants were shown that the average life expectancy in The Netherlands equals approximately 85 years.

Variable	Definition
	Panel C: Pension
Pension income	Individual annual before tax second pillar accrued pension rights.
Pension income max	Projected individual annual before tax second pillar accrued pension rights.
Other pension income	Self-reported individual annual before tax second pillar pension benefits received from other pension funds (e.g. accrued in the past) in one of the classes: 0 = none, (< 1,000), (1,002-5,000), (5,001-10,000), (10,001-20,000), (20,001-30,000), (30,001-50,000), (50,001-100,000), (> 100,000)[a]
Individual pension income	Self-reported individual annual before tax pension benefits received from insurance companies or banks in one of the classes: 0 = none, (< 5000), (5,001-10,000), (10,001-30,000), (30,001-50,000), (50,001-100,000), (100,001-200,000), (> 200,000)
Part-time pension	Dummy; 1 = administrated part-time pesion; 0 = no part-time pension
AOW bridge	Dummy; 1 = administrated AOW bridge (second pillar financial compensation in case of early retirement); 0 = no AOW bridge
Flexible pension	Dummy; 1 = administrated flexible pension in the form of a high-low or low-high annuity; 0 = no flexible pension
Transfer partner pension	Dummy; 1 = administrated transfer of partner pension to old age pension; 0 = no transfer of partner pension
Intended retirement age	Intended retirement year with respect to the statutory retirement age in one of the classes (negative values indicate early retirement, positive values indicate later retirement): (< -5), (-5), (-4), (-3), (-2), (-1), (1), (2), (3), (> 3).
Att. pension choices	Classes; 1 = strongly disagree with more freedom of pension choices, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree with more freedom of pension choices
Att. premium stop	Classes; 1 = strongly disagree with the choice premium stop, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree with the choice premium stop
Att. flexible pension age	Classes; 1 = strongly disagree with the choice of a flexible pension age, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree with the choice of a flexible pension age
Att. flexible pension benefits	Classes; 1 = strongly disagree with the choice a flexible pension benefits, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree with the choice a flexible pension benefits
	Panel D: Other
Life expectancy	Expected life expectancy in years reported in one of the classes: (< 75), (75-84), (85), (86-90), (> 90)[c]
Duration	Minutes between starting and ending the survey
Complexity	Classes; 1 = very easy survey, 2 = easy, 3 = neutral, 4 = difficult, 5 = very difficult survey

Table 12: **Median individual tax levels in The Netherlands for active participants and retirees.** Tax levels are based on individual annual before tax income. We constructed the tax levels for actives by adding 10 percentage points to the tax level of the corresponding income level for retirees.

	Tax (fraction income)	
Income (€)	Active participants	Retirees
<17,802	0.19676	0.09676
<20,018	0.18671	0.08671
<21,849	0.20572	0.10572
<23,731	0.23090	0.13090
<26,327	0.24774	0.14774
<29,729	0.26721	0.16721
<34,250	0.28571	0.18571
<40,542	0.29940	0.19940
<51,792	0.35565	0.25565
<65,000	0.39650	0.29650
<80,000	0.42698	0.32698
≥80,000	0.48345	0.38345

Table 13: **Robustness winsorization level of 1%.** Panel A shows the two-limit tobit maximum likelihood estimates for all participants for the present-bias factor, discount factor, and CRRA utility, similar to Table 2 but now preferences are winsorized at a 1% level. Panel B reports the number of retirees for which individually estimated preferences (winsorized at a 1% level) explain actual annuity choices using an indifference bandwidth of at most $\varepsilon = 2\%$, similar to Panel B in Table 4.

Panel A: Present bias, annual discounting, and curvature parameter estimates

	Median	Mean	Standard Deviation	25^{th} Percentile	75^{th} Percentile	N
Present-bias factor	0.836	0.832	0.318	0.694	0.953	1062
Discount factor	0.989	1.050	0.394	0.962	1.043	1062
Annual discount rate	0.011	0.006	0.193	-0.041	0.039	1062
CRRA curvature	0.965	0.919	0.577	0.905	0.987	1062

Panel B: Explanatory power of preferences for annuity choices

			Actual		
			Flat	Front-loaded	Total
Annual cons. difference ≤ 0.02	Expected	Flat	205	23	228
		Front-loaded	43	86	129
		Total	248	109	357