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van der Lecq, Fieke; Dellaert, B.G.C.; Alserda, G.A.G.; Swinkels, L.A.P.

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Individual pension risk preference elicitation and collective asset allocation with heterogeneity☆

Gosse A.G. Alserda[a], Benedict G.C. Dellaert[a,b], Laurens Swinkels[a,*], Fieke S.G. van der Lecq[c]

[a] *Erasmus School of Economics, Erasmus University Rotterdam, Burgermeester Oudlaan 50, Rotterdam 3062PA, The Netherlands*
[b] *Monash Business School, Monash University, Australia*
[c] *School of Business and Economics, Vrije Universiteit Amsterdam, Netherlands*

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ABSTRACT

Collectively organized pension plans must increasingly demonstrate that the risk preferences of their members are adequately reflected in the plans' asset allocations. However, whether funds should elicit individual members' risk preferences to achieve this goal, or whether they can rely on other indicators, such as socio-demographics, remains unclear. To address this question, we apply a tailored augmented lottery choice method to elicit individual pension income risk preferences from 7894 members from five different pension plans. The results show that member risk preferences are strongly heterogeneous and can only partially be predicted from individual and plan characteristics. Differences in risk preference imply different optimal asset allocations. We find large welfare losses for heterogeneous members in pension plans with their current asset allocation because these allocations are safer than implied by members' preferences. We provide a framework for pension plans to gauge the need to elicit risk preferences among their members.

1. Introduction

Pension capital is a major component of savings for many individuals worldwide, and pension funds are some of the largest investors in the world, with considerable impact on stock markets (Organisation for Economic Co-operation and Development, 2015b). The investment decisions of pension funds also impact the retirement income of large segments of the population (Organisation for Economic Co-operation and Development, 2015a). Optimal pension asset allocation is a rigorous financial optimization process that takes into account projected retirement ages and desired replacement ratios, among others. For individual retirement accounts, the members themselves are responsible for processing this information to find the asset allocation that best suits their situation. However, in collectively organized pension plans, where members are forced to share the same asset allocation, the board of trustees is responsible for ensuring that the pension plan asset allocation adequately reflects the collective risk attitude of its members. This requirement is challenging, because the risk preferences of members are not directly observable. Moreover the measurement of risk preferences can be noisy (Dave et al., 2010). The challenges in accurately measuring risk preferences could be why, as far as we know, risk preference measurements have hardly been used as input to determine pension plan asset allocation. The little research that has been done has measured substantially lower levels of risk aversion when directly eliciting pension members' preferences through surveys, than the level of risk aversion used when calibrating optimal pension asset allocations (Mankiw and Zeldes, 1991; Barsky et al., 1997). Therefore, pension funds currently lack a clear basis for determining whether they should elicit individual members' risk preferences, or whether they can rely on other indicators such as sociodemographics. In addition, it is not clear what the welfare loss is when individuals are forced into a collective pension asset allocation that does not match their risk preferences. We aim to fill both gaps in the literature.

Doing so is important because the literature shows substantial heterogeneity in (investment) risk preferences among individuals (e.g., Holt and Laury, 2002; Harrison et al., 2007; Paravisini et al.,

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* Corresponding author.
E-mail address: lswinkels@ese.eur.nl (L. Swinkels).

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2017). Moreover, the current pension asset allocation models, such as those of Campbell et al. (2003), and Viceira (2001) show that risk preferences are an important input for optimal asset allocation. However, despite this research, Clark and Bennett (2001) and Frijns (2010) find that many pension funds pool investments such that everyone has the same asset allocation, which clearly ignores heterogeneity in risk preferences. such allocation could be optimal in the case of pure defined benefit (DB) schemes, where all investment risks are borne by the employer(s) and the pensions are risk-free for the fund members. However, it is likely to be detrimental to members in the case of collective defined contribution (CDC), in which case the members bear the risk of investment and the collectively set asset allocation might not match members' risk preferences. Heterogeneity creates a two sources of welfare loss for individual members: First, collective welfare loss arises when a collective asset allocation does not match the population's (average) risk preferences. Second, an individual welfare loss arises because of heterogeneity in risk preferences between members within the fund. Our results are also important in the case of individual defined contribution (DC) schemes. Individual retirement accounts typically offer a collectively set life-cycle asset allocation that is age dependent. If the life-cycles are also dependent on pension risk preferences, insights from our elicitation method could be used.

Three factors distinguish the pension domain from other finance domains, which makes a domain-specific analysis of how individuals' risk preferences affect optimal asset allocation especially relevant. First, choices in pension plans are mostly made by delegation. Pension plan members need not to have the financial literacy necessary to make adequate choices for retirement savings (e.g., Lusardi and Mitchell, 2007; Balloch et al., 2014). Nevertheless, their preferences should be taken into account in pension scheme design. This calls for an instrument that measures member risk preferences, without being too demanding. Second, state pensions and income taxes can influence pension asset allocation (Fischer and Jensen, 2015). This calls for a contextual analysis of individuals' risk preferences. Third, in many countries pension plan participation is mandatory, such as through collective labor agreements. Since members cannot exit these pension plans, their preferences should be incorporated to keep the pension system sustainable. In addition, risk preferences are domain dependent, meaning that individuals have different risk preferences depending on the domain to which the choice refers (Weber et al., 2002; Van Rooij et al., 2007). Pensions are cognitively classified as a separate risk-decision domain by individuals, and financial risk aversion is higher in the pension domain than in other financial domains (Van Rooij et al., 2007). This implies that risk preferences should be elicited within the context of the pension domain to be relevant to pension fund decision making.

The contribution of this paper is twofold. First, we design a novel questionnaire to measure risk preferences in the pension domain and relate the responses of pension scheme members to their socio-demographic characteristics. Second, we analyze the welfare gains of allowing pension fund members an asset allocation that is different from the average of the pension fund. Despite research on the investment consequences of pension plan age heterogeneity (Bikker et al., 2012; Molenaar and Ponds, 2012), the extent to which allowing for pension plan member risk preference heterogeneity will affect optimal asset allocation in real-world settings remains unclear.

These real-world settings are changing, since many sponsors are shifting from DB plans to DC or CDC plans. CDC plans are sometimes also called defined ambition, since sponsors do not make extra contributions in cases of funding rate deficit. In CDC plans, the investments are made collectively and individuals are not allowed personal asset allocations. However, the collective asset allocation should reflect the demands of the fund population, in terms of both age and risk preferences. By implication, the elicitation of risk preferences is useful in collective plans as well, as long as the members are exposed to investment risk. This is the very setting in which we conducted our surveys: CDC plans in which plan members are exposed to investment risk. Although such CDC plans are most widespread in the Netherlands, we note that they are also well known in the United Kingdom, as well as in European Union member states that want to enhance their second pillar.[1] A description of the three pillars is provided in Appendix A.

We use unique data from 7894 members in five Dutch pension plans that completed our novel questionnaire to assess the value of matching asset allocations to individual risk preferences. Our augmented lottery choice method is tailored to individual pension risk preference elicitation. Lottery choice questions (Holt and Laury, 2002) are personalized to each individual's pension income based on current income to accurately reflect risk return trade-offs. The augmented lottery choice method combines information from lottery choices with the observations of two other risk preference elicitation methods (Van Rooij et al., 2007; Kapteyn and Teppa, 2011) to reduce the level of measurement noise in the risk preference measure.

This augmented lottery choice method allows us to determine the pension plan population characteristics and assumed equity premiums for which individual member pension risk preferences should be elicited to ensure an adequate fit between pension plan asset allocation and member preferences. This question is vital from both a pension fund and a societal perspective, because substantial retirement welfare losses can affect pension plan members if there is a mismatch between their risk preferences and the plan's asset allocation. This can imply, for example, that members incur a greater risk of a low pension income than they wish to have or that they will lose out on an equity premium they would prefer to have. However, when the impact on asset allocation is small, pension funds can largely ignore differences in preferences among members in plan asset allocation, saving on costly, time-consuming risk preference elicitation.

2. A novel measure for eliciting pension plan member risk preferences

During their working lives, pension plan members contribute a substantial proportion of their incomes to pension capital. The optimal asset allocation for an individual depends, among other things, on the individual's risk preferences (Bodie et al., 1992; Viceira, 2001; Campbell et al., 2003). Research shows that individuals differ significantly in terms of how they trade off (expected) returns with risk in financial investments (Tversky and Kahneman, 1992; Holt and Laury, 2002; Weber et al., 2002). Therefore, members are likely to also differ in terms of the extent to which they trade off (expected) pension benefits and the riskiness of those benefits. This implies that the optimal pension asset allocation likely differs among members.

In this paper we explicitly model pension members' normative risk preferences. Normative risk preferences can deviate from revealed risk preferences due to well described measurement irregularities, such as probability weighting, loss aversion and the reflection effect (Tversky and Kahneman, 1992; Bleichrodt et al., 2001; Beshears et al., 2008). The elicitation methods are selected to minimize measurement biases (e.g., by avoiding certainty effects), but we do not adjust the results in order to address pos-

[1] See, for example, the Defined Ambition Research Briefing (September 2014) in the UK House of Commons Library: http://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN06902 or Pension & Investments (December 2016), "Germany gearing up for new mandatory DC plan: Proposal borrows much from collective hybrid system of the Netherlands."

sible behavioral effects, since that would lead to many arbitrary choices. Behavioral effects are minimized by combining multiple elicitation methods in the composite score, which is the measure of risk preferences that combines the information of the different elicitation methods. Our results use expected utility (EU) with constant relative risk aversion (RRA) as the preferred model for normative risk preference. Although EU is generally accepted as the model for normative risk preferences (Quiggin, 2012), it does not always match actual behavior, such as stock market nonparticipation (Ang et al., 2005). To explain revealed preferences, other utility functions can be used, including behavioral effects such as loss aversion (Benartzi and Thaler, 1995). We leave examination of the impact of applying these more behavioral models on optimal pension asset allocation to future research.

To express the risk preferences of members, we construct a pension-specific metric based on individuals' constant[2] RRA (γ) coefficient, a common financial measure of risk preferences (Chiappori and Paiella, 2011). This metric expresses how risk averse an individual is with respect to pension wealth or retirement income. It captures risk aversion in a single coefficient, that is independent of an individual's wealth and can be easily used to assess distributions of pension outcomes.

Positive values of γ indicate risk aversion, and negative values indicate risk-seeking. A value equal to zero indicates risk neutrality. Individuals who are more risk averse require higher return premiums before they are willing to accept a risky investment. In the EU framework, risk aversion depends on the concavity of the utility function (Pratt, 1964; Arrow, 1965), and can therefore be defined as:

$$\gamma_i = P_i * \frac{-U''(P_i)}{U'(P_1)} \tag{1}$$

where γ_i is the (constant) RRA and P_i is the pension income of individual i, and U' and U'' are the first and second derivatives, respectively, of U, which is the pension income utility function.

From expression (1), it is clear that the value of γ depends on the shape of the utility function. To infer preferences for pension risk from observed risky decisions (e.g., lottery choices), we use the following power utility function (Holt and Laury, 2002; Harrison et al., 2007):

$$U_i(P_i) = \frac{P_i^{1-\gamma_i}}{1-\gamma_i} \tag{2}$$

where U_i is the utility, P_i is the pension income, and γ_i is the (constant) RRA for individual i.

Next, EU can be used to compare different asset allocation options for each individual. The EU of an asset allocation is obtained by multiplying the utility of each outcome by the probability of that outcome. The option that has the highest EU represents the option that provides the highest utility to an individual, on average over possible outcomes, given the individual's RRA.

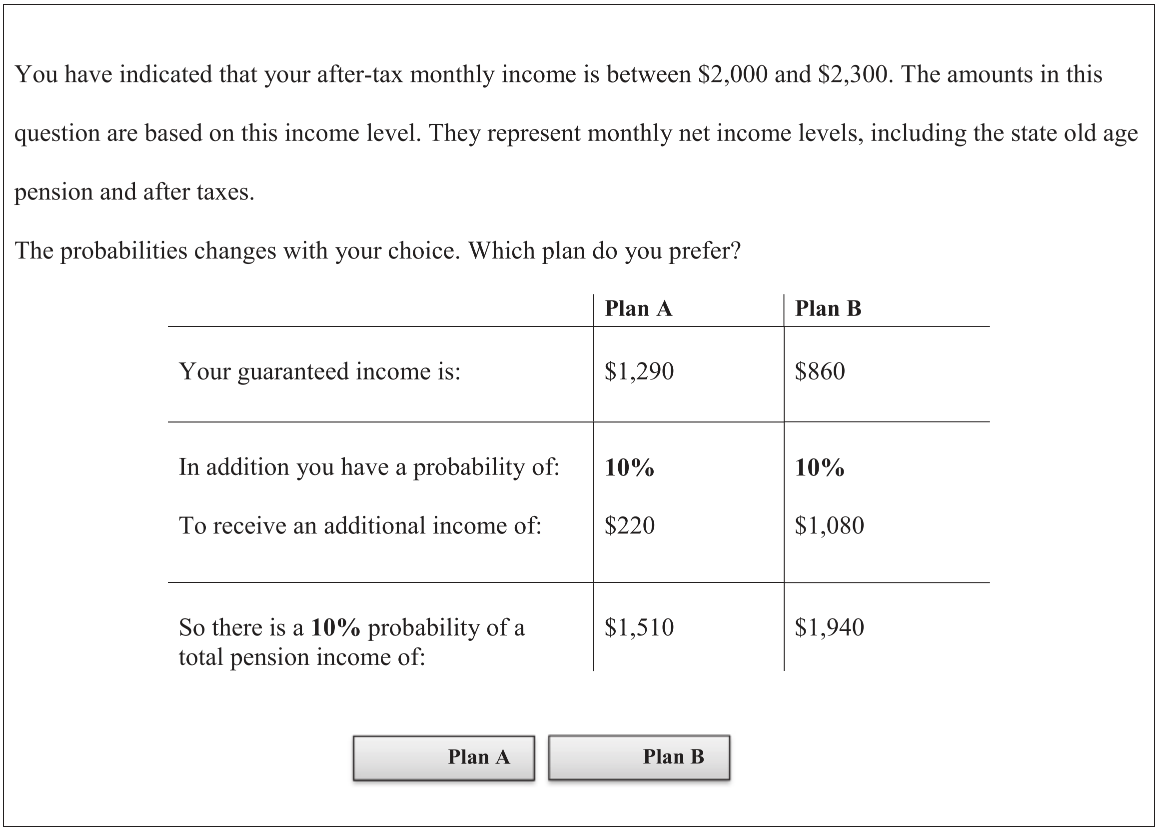
This approach provides pension plan managers a metric to calculate the fit between the pension plan's asset allocation and members' risk preferences, if these preferences are known. Managers tend to make investment decisions primarily on the basis of performance targets (March and Shapira, 1987). These performance targets might not (perfectly) represent the members' risk preferences. To avoid this potential mismatch, supervisors, such as central banks, are increasingly demanding that pension plan managers ensure that their asset allocation adequately reflects individual pension plan members' risk preferences (Rozinka and Tapia, 2007; Frijns, 2010; European Insurance and Occupational Pensions Authority, 2013). Pension plan managers can match asset allocation to members' risk preferences only if their risk preferences are known. Nevertheless, it is unclear whether plan managers should elicit individual members' risk preferences as input in this process or whether they can rely on other indicators, such as sociodemographics and industry employment to project member risk preferences (Bikker et al., 2012). To disentangle the determinants of pension risk preferences, we develop a measurement instrument for individuals' risk preferences tailored to the pension domain and observe the heterogeneity in members' preferences in five Dutch pension plans, which are connected to different pension funds.

The elicitation of risk preferences in this study expands and tailors the traditional multiple lottery choice (MLC) method (Binswanger, 1980; Holt and Laury, 2002). The MLC method is a well-accepted risk preference elicitation method (Pennings and Smidts, 2000; Andersen et al., 2006; Harrison et al., 2007; Dohmen et al., 2011). It introduces a series of choices between two lotteries. Both lotteries have a good and a bad state, with equal probabilities of realizing either state for each question. The lotteries differ in their dispersion: the "safe" lottery has outcomes that do not deviate much, while there are large differences between the good and bad states for the "so-called risky" lottery. For the first question (see Fig. 1), the probability of the good state is low, making the safe lottery dominant for all except extremely risk-seeking individuals. In subsequent questions, the probability of the good state increases, gradually making the risky lottery more attractive. The higher an individual's risk aversion, the more questions it will take before the individual switches from the safe to the risky lottery. To accept the bad state of the risky lottery, risk-averse individuals demand a higher risk premium, which is defined as the difference between the expected values of the risky and safe lotteries.

Although the MLC method is well accepted and frequently used, it is cognitively demanding for the respondents. At least four challenges need to be addressed. First, the results from this method are often noisy, since members find it difficult to choose their preferred trade-off when utility differences are small, and the results tend to depend on the exact framing of the question. Second, a substantial number of respondents are found to choose a dominated option, that is, an option that has lower outcomes in both states of the world. Third, the RRA results of previous studies are limited to ranges rather than to a specific point, as necessary in asset allocation. Finally, previous studies are not linked to the pension domain and are not related to respondent income (Holt and Laury, 2002; Harrison et al., 2007; Dave et al., 2010). For pensions, this is a prerequisite, because of the domain dependency of risk preferences. In particular, individuals have different risk preferences depending on the domain of the risky choice (Weber et al., 2002; Van Rooij et al., 2007).

In our study, we tailor the MLC method to the pension domain and propose to augment its results with information from additional measures to overcome the previously mentioned concerns (i.e., domain dependency, measurement noise, and cognitive challenges that lead to the selection of dominated options). First, the amounts involved in both lotteries relate to the pension domain are denoted in local monetary units, that is, euros, include the state old age pension, and are after tax. The amounts presented to the respondents are derived from their monthly incomes and are either 60% (bad state) or 70% (good state) of their current net income for the safe lottery and 40% (bad state) or 90% (good state) of their current net income for the risky lottery. The state's old age pension and taxes are included in these amounts resemble actual situations as closely as possible. An example of the resulting question, converted to U.S. dollars, is presented in Fig. 1. This representation is the result of various testing rounds, that showed that this visual representation led to the best understanding among re-

[2] Although RRA is ex ante assumed to be constant with income/wealth, we do add income in a regression to try to explain risk aversion.


You have indicated that your after-tax monthly income is between $2,000 and $2,300. The amounts in this question are based on this income level. They represent monthly net income levels, including the state old age pension and after taxes.

The probabilities changes with your choice. Which plan do you prefer?

	Plan A	**Plan B**
Your guaranteed income is:	$1,290	$860
In addition you have a probability of:	**10%**	**10%**
To receive an additional income of:	$220	$1,080
So there is a **10%** probability of a total pension income of:	$1,510	$1,940

Plan A **Plan B**

Fig. 1. Example of adjusted MLC question.
Notes: Example for a member with a net monthly income of $2,150. This example represents the first choice out of a sequence of 10 in which the probability (bold) systematically increases for the additional pension income. The currency of the Netherlands is Euro, which is used throughout the questionnaire. Here, we convert all amounts to U.S. Dollars.

spondents. However, that does not mean that our representation is optimal. We leave improvements on the visual aspects of our questionnaire for future research.

When the respondent chooses Plan B, the MLC is finished. When the respondent chooses Plan A, the next question looks the same as in Fig. 1 but the probability increases from 10% to 20%. Each possible switch-point in the MLC method corresponds to an RRA range. This range can be obtained by calculating, for each choice, the RRA value that makes an individual indifferent between the two options. Assuming a power utility function (Eq. (2)) and linear probability weighting yields a closed-form solution that can be easily solved (Holt and Laury, 2002). The RRA range for a given switch-point is then the range between the point of indifference for the last choice of the safe lottery and the point of indifference for the first choice of the risky lottery.[3] The results of these calculations are presented in Table 1 and are irrespective of income, since the options are constant shares of income.

Next, in line with Kapteyn and Teppa (2011), the results from the MLC method are combined with the results from two less time-consuming and cognitively less demanding questions about pension risk preference to form a single composite score (Van Praag, 1991; Abdellaoui et al., 2011).[4] The composite score should reduce noise and thus provide more stable measures of risk preferences (Ackerman and Cianciolo, 2000). Unlike the MLC method, these methods do not involve amounts and probabilities and therefore do not allow for computation of an RRA coefficient, which are necessary to determine an optimal asset allocation.

Table 1
Adaptation of the Holt and Laury MLC method.

Number of safe choices	Equal to switch-point with probability of good state	Range of relative risk aversion for $U_i(P_i) = P_i^{1-\gamma_i}/1-\gamma_i$
0	10%	$\gamma < -4.82$
1	20%	$-4.82 < \gamma < -3.00$
2	30%	$-3.00 < \gamma < -1.82$
3	40%	$-1.82 < \gamma < -0.86$
4	50%	$-0.86 < \gamma < 0.00$
5	60%	$0.00 < \gamma < 0.85$
6	70%	$0.85 < \gamma < 1.76$
7	80%	$1.76 < \gamma < 2.85$
8	90%	$2.85 < \gamma < 4.46$
9–10	100%	$4.46 < \gamma$

Notes: Ranges of RRA scores depending on the number of safe choices / switch-point.

[3] Later, we transform the composite pension risk scores back to RRA levels. For that step, we use specific values of the RRA instead of ranges. To obtain these values, we simulate for each individual a specific RRA within the range from a uniform distribution. For the one open interval with an RRA above 4.46, we use a recursive method to determine the distribution of RRA levels in the tail. We first calculate the mean and standard deviation of the RRA levels when the entire distribution is concentrated at the minimum RRA of 4.46. We then use this standard deviation to create a normal distribution in the tail beyond 4.46. However, since the estimated standard deviation was underestimated in the first step, we re-estimate it and calculate the tail distribution with this new and somewhat higher standard deviation. We repeat this process until convergence is obtained. The stopping criterion is set to be that the change from the re-estimation is smaller than 0.00001% of the standard deviation.

[4] We also tested an additional question in the survey based on Kapteyn and Teppa (2011) - “My friends describe me as a careful person” - but the factor analysis and item response analysis showed that this item was not well correlated with the other three measures. Hence, we omitted it from the proposed risk measurement approach.

The first question is a self-description task based on the work of Kapteyn and Teppa (2011): “Are you willing to take risk with your pension?” which is to be answered on a seven point Likert scale (“completely agree” = 1 to “completely disagree” = 7). The second question is a simplified portfolio choice question adjusted from Van Rooij et al. (2007), where the respondents must divide their pension capital between equity (described as risky investments with an expected return of 6% per annum) and bonds (described as savings with a guaranteed return of 2% per annum). We mention the expected returns explicitly to increase the likelihood of the respondents' answers reflecting risk aversion and being less influenced by ambiguity aversion with respect to their own (conditional) expected returns on stocks and bonds.

The composite score is formulated as the average of the standardized risk preferences of all the elicitation methods (Ackerman and Cianciolo, 2000). Factor analysis and item response theory are used to verify whether all the elicitation methods load on one common underlying risk preference factor. If a respondent has failed to respond to one of the elicitation methods, only the observed values are included in the composite score for that person. The composite measure is thus the average of the standardized elicitation results.

Since the MLC method is the only method that allows us to measure risk preferences in terms of RRA, the composite score is then fitted on the RRA domain by regressing the RRA measure of the MLC method on the composite score by means of the following equations:

$$MLC_i^{\gamma} = \alpha + \beta * Composite_i + \varepsilon_i \tag{3}$$

$$\widehat{MLC}_i^{\gamma} = \hat{\alpha} + \hat{\beta} * Composite_i \tag{4}$$

Where *Composite* represents the Composite Score (γ) and hats represent estimated values. We assume measurement noise to be independent and identically distributed. The γ from the augmented MLC, which is based on the regression results without the error term, will therefore contain substantially less measurement noise. Hence, we obtain more robust RRA coefficients (i.e., a less biased and skewed distribution thereof) that can be used to determine the optimal asset allocation for individual pension plan members.

3. Empirical assessment of risk preference heterogeneity in the pension domain

Large-scale data collection was conducted to empirically assess the effect of heterogeneity in risk preference on optimal asset allocation. Data were collected through an online survey of pension plan members of five Dutch company pension funds that all provide CDC pension schemes. The survey was conducted in the second pillar of the pension system, which consists of capital-based collective pension plans. Most Dutch employees are covered by such a second pillar pension plan. Participation is mandatory for those employed in a firm with a corporate or industry-wide pension plan. Most pension plans in the Netherlands contain risk-sharing elements between employer(s) and employees, although the amount of risk borne by the employee has increased considerably. Strategic pension plan asset allocation is set by the board of trustees, where pension contributions by the employer and the employees are traded off against pension outcomes. By implication, the employees are exposed to investment risk, even though they cannot determine their individual asset mixes. Appendix A describes the essential features of the pension system in the Netherlands and compares the system with that in the United States where appropriate.

Our survey was conducted among members of second pillar pension funds for five pension funds of similar organizational structure but covering members of very different industries, ranging from blue collar to white collar. The survey was administered in collaboration with a consultancy firm and sent to several of its clients, that is, companies with pension plans administered by different pension funds. Before the survey was sent out, it was first tested using a paper version on a small representative population and then tested online with the consultancy firm's own 172 employees. After minor adjustments, the questionnaire was sent to the active members of five pension plans from five companies from four industries (transportation, manufacturing, automotive, and leisure). All plan members were invited via regular mail and/or e-mail, depending on their channel preferences and the contact possibilities of the companies' pension funds. The surveys were conducted in the first half of 2013. Table 2 contains summary data for the aggregate sample and for each pension plan separately.

The response rate is on average 14.1%, and varies between 5.5% and 42.4%. Differences in response rate could be due to the method of inviting respondents and company efforts in requesting that members complete the survey. Invitations by regular mail resulted in markedly lower response rates, and e-mail reminders sent out by the employer increased response rates. Members were not paid and did not receive other forms of compensation for completing the questionnaire. Although the questions were not directly incentivized, pension funds indicated in the invitation that the results would be taken into account for future decisions, so participation in the survey was consequential.

Men were more likely to fill out the questionnaire for each of the five pension plans. On average, our sample consists of 82% men, while the population has 69% men. Note that the first three pension plans have primarily a male workforce, whereas the fourth has a female workforce. The respondents are also slightly older than the nonresponders for four out of five pension plans, with an average age of 50.1 years for the responders, while the population average is 47.8 years old. For two of the pension plans, the population average income is available. The respondents' income is slightly higher for the third pension plan, and slightly lower for the fifth pension plan, compared to their population averages. We have no information on the education level of the population, so we cannot determine whether there is over- or underrepresentation. In summary, our response rate is high, there is substantial variation across pension plans, and the sample of respondents does not exhibit substantial selection bias.

3.1. Empirical assessment of risk preferences in the pension domain

The questions that we asked relate to the risk pension members are willing to take with their pension income, including social security, after retirement. The reason for this approach is that it not only relates to the cognitive capabilities of the respondents to mentally separate out these pension components but also reflects that it is their total pension income and not the source of the pension income that is relevant to their consumption. By implication, the asset allocation for the second pillar pension plan needs to be calculated after deducting the expected first pillar pension income, which we treat as certain since it is provided for by the government. Our model allows us to calculate differences between outcomes based on the pension asset allocations that are the same for all members in a plan, and pension asset allocations that are tailored to individuals' estimated risk preferences. We can thus infer the welfare loss of being forced into an asset allocation that does not match an individual's risk attitude. The caveat remains that these statements are conditional on the simulation model that we use for the assets and the utility framework that we assume the member to have.

Table 2
Summary data.

Pension plan		1	2	3	4	5	Total
Response	Sample	5094	1176	873	437	314	7894
	Total	29,738	11,093	2057	8015	4211	55,114
Response rate		17.1%	10.6%	42.4%	5.5%	7.5%	13.3%
Gender = man	Sample	86%	90%	80%	25%	66%	82%
	Total	78%	85%	76%	20%	55%	69%
Average age	Sample	50.1	53.8	44.8	52.2	48.5	50.1
	Total	47.4	51.3	45.1	47.6	43.1	47.8
Average monthly income	Sample	$2537	$2097	$2168	$1813	$2498	$2396
	Total	–	–	$1898	–	$2648	–
Average education	Sample	3.8	3.0	3.5	4.5	4.1	3.7
Has partner	Sample	86.5%	87.6%	84.1%	80.1%	80.9%	85.8%
Home-owner	Sample	86.3%	76.9%	82.0%	81.2%	84.4%	84.3%

Notes: Number of observations, response rates, % men, average age, average monthly net income, average education (education ranging from 1 (attended primary education) to 6 (attended university)), % with partner, and % that owns a house for total population of the pension plan and the sample of respondents.

Table 3
Responses to elicitation methods.

Multiple lottery					Stated risk aversion			Bond allocation			Composite measure			
Safe choices	γ		Freq.	%	Likert scale	Freq.	%	Allocation(%)	Freq.	%	γ		Freq.	%
0	$-\infty$	−4.8	1243	15.8	Seeking			0	42	1.3	$-\infty$	−4.8	0	0,0
1	−4.8	−3.0	207	2.6	1	150	1.9	10	25	0.8	−4.8	−3.0	9	0.1
2	−3.0	−1.8	213	2.7	2	508	6.4	20	90	2.8	−3.0	−1.9	153	1.9
3	−1.8	−0.9	428	5.4	3	1665	21.1	30	175	5.4	−1.9	−0.9	429	5.4
4	−0.9	0.0	712	9.0	4	1208	15.3	40	271	8.4	−0.9	0.0	688	8.7
5	0.0	0.9	779	9.9	5	1647	20.9	50	668	20.6	0.0	0.9	1176	14.9
6	0.9	1.8	1113	14.1	6	1686	21.4	60	349	10.8	0.9	1.8	1211	15.3
7	1.8	2.9	1157	14.7	7	1012	12.8	70	456	14.1	1.8	2,9	1612	20.4
8	2.9	4.5	669	8.5	Averse			80	404	12.5	2.9	4.5	1704	21.6
9	4.5	∞	1188	15.1				90	322	9.9	4.5	∞	912	11.6
10			177	2.2				100	435	13.4				
Total			7886	100	Total	7876	100	Total	3327	100	Total		7894	100

Respondents' risk preferences were elicited using three different risk elicitation methods: the MLC method, the Likert scale self-description method, and the portfolio choice method. The measures varied in their level of complexity and practical usage. The more complicated MLC method might yield noisier results, but is less likely to lead to socially desirable answers. The MLC is also the only one question from which we can back out RRA coefficients that can be used as an input parameter for optimal asset allocation.

Table 3 presents the results from each of the individual questions and the composite measure that we constructed. In contrast to the other methods, the question regarding preferred bond allocation was not set to be required to answer, which resulted in roughly half of the responses. The group of nonresponders to this question did not answer other questions substantially different from the group of responders.

The empirical evidence in the first columns of Table 3 suggests that some of respondents had difficulty with the MLC question, since 2.2% of the respondents chose the dominated answer of 10 safe choices. This is comparable to other applications (Holt and Laury, 2002); however, it suggests that a few respondents did not fully understand the question or did not spend enough time on answering it. This indicates that using information from other, possibly easier to answer questions relating to risk aversion in the pension domain, can increase the reliability of the results.

Since only five of the safe choices correspond to risk aversion, we see that about 35% were categorized as risk seeking in answering the MLC question, with a peak for the first answer at 15.8%. Perhaps some of these most risk-seeking respondents did not interpret the question correctly. Therefore, we disregard the MLC answers with zero safe choices and instead use imputed values based on the respondents' sociodemographic information. The frequency distribution also suggests that more granularity at higher risk aversion levels could have been better, since the number of respondents with six to nine safe choices does not seem to decrease. Moreover, the current asset allocations of the pension funds in our sample correspond to levels of RRA above 4.5. Based on our survey results, participants would, on average, be better off if pension funds increased their collective equity allocations.

The pension asset allocation question indicates that many members are willing to take on risk, since about 35% is willing to invest 80% or more in equities. The question about stated risk aversion might be the least cognitively demanding, but could also lead to socially desirable answers. At least in this case, we see that most of the answers are in the range four to six, suggesting moderate to high risk aversion. Even though all the columns in Table 3 are sorted with the most risk-seeking answers at the top, the rows do not necessarily correspond to the same risk preferences. For example, the first five choices of the MLC method differentiate between risk-seeking individuals, who, by nature, should allocate 100% of their financial wealth to equities.

We employ a principal component analysis, which shows that the MLC method, the pension-related self-description question, and the portfolio choice method load on a common factor (with factor loadings of 0.87, 0.82, and 0.50, respectively, together explaining 57.8% of the variation). In addition, Table 4 shows the results of item response theory analysis. The results show that all three methods are positively correlated to the latent variable, but to different degrees. The self-description question has greater discriminative power (are less noisy) and are more strongly correlated

Table 4
Item response theory and correlation matrix.

Item response theory results				Correlation matrix			
Measure	Discrimination	Difficulty (range)		θ IRT	MLC	Stated aversion	Allocation to bonds
		min	max				
MLC	0.724 (0.026)	−2.582 (0.093)	2.362 (0.089)	0.316	1.000		
Stated aversion	4.649 (0.389)	−2.227 (0.042)	1.220 (0.023)	0.972	0.255	1.000	
Allocation to bonds	1.876 (0.073)	−3.082 (0.115)	1.510 (0.048)	0.744	0.162	0.615	1.000

with the estimated latent variable. This positive but not perfect correlation is indicative of the added value of a composite measure that combines simpler (more reliable) and more demanding questions. The results of the principal component analysis and the item response theory analysis suggest that the methods describe a common latent variable, which we feel comfortable defining as risk aversion. Noise present in the measurement of risk preferences is reduced by combining the information from these three questions.[5] This approach allows us to combine the three elicitation methods into a single composite score, scaled to RRA (see Section 2). The resulting values of the rescaled composite score are presented in Table 3. Histograms of the composite score per pension plan are shown in Appendix B.

We find RRAs with a mean value of 1.926 and a standard deviation of 1.901. This mean value is categorized by Holt and Laury (2002) as indicating high risk aversion. This result confirms the findings of Van Rooij et al. (2007), who find that risk preferences are relatively high in the pension domain. However, note that. in the optimal asset allocation literature, typically higher levels of risk aversion are needed to explain observed asset allocations in practice. For example, Viceira (2001) life-cycle asset allocation model uses coefficients of RRA ranging from one to 10.[6] The standard deviation of 1.901 indicates that individuals are strongly heterogeneous in their degrees of risk aversion. We now examine whether this heterogeneity can be explained by sociodemographic characteristics.

3.2. Drivers of heterogeneity in pension risk preferences

We analyze the extent to which the observed heterogeneity in pension risk preferences is predictable from directly observable member characteristics. If the heterogeneity can be explained, pension scheme trustees could use these easily available characteristics instead of sending out questionnaires as we did. Based on the literature, our prior is that it is difficult to accurately predict risk preferences, since a substantial amount is difficult to measure, it being either inherited or acquired (Cesarini et al., 2009).

We use an ordinary least squares regression model with the results of the separate elicitation methods, including the composite score as the dependent variable, expressed in terms of RRA when applicable, and a set of sociodemographic characteristics. The estimation results are presented in Table 5. We include pension plan dummies as independent variables to represent the current pension system where asset allocation differs only across pension plans, not members. The first part of each method shows that risk preferences do seem to vary across pension plans, ranging from an average of 1.83 for the first and numeraire pension plan to 2.41 for the fourth pension plan in the case of the composite score. In addition to differences in the average level of risk preferences, heterogeneity levels within plans also seem to differ. The standard deviation of the composite score ranges from 1.65 for the third plan to 2.01 for the second plan. We thus observe significant differences between the risk preferences of different pension plan populations.

Adding sociodemographic information substantially increases the explanatory power of the model, with an increase in R^2 for the composite measure, from 0.007 to 0.056, and reduces the effect of the pension plan dummies. Table 5 indicates that RRA is negatively correlated with income and positively with age, in line with the results of Watson and McNaughton (2007). The quadratic terms suggest that both effects decline with higher levels of income and age, respectively. Men and home-owners are, on average, less risk averse, while having a partner is positively correlated with RRA. Finally, higher levels of education correspond to lower levels of RRA. Due to the addition of sociodemographic information, the coefficients of the pension plan dummies are reduced and only the coefficient of the fifth plan remains significant. The differences between pension plans populations therefore mainly originate from differences in sociodemographic compositions of the population and less from potential risk preference selection effects.

The empirical evidence presented here is consistent with the notion that heterogeneity in risk preferences is mainly present at the individual member level and to a far lesser extent at the pension plan level. Note that R^2 increases from 0.008 to 0.017 when sociodemographic measures are added to the pension plan dummies for the MLC, whereas it increases to 0.056 for our composite measure. Although the composite measure reduces noise, there is still an enormous amount of variation left to explain. This unexplained variation is only slightly higher than for the two less cognitively demanding questions. However, our analysis cannot rule out that remaining noise is responsible for the observed heterogeneity at the individual level.

One of our contributions to the literature is to empirically demonstrate heterogeneity in risk preferences both within pension plans and between the populations of different pension plans. Moreover, we show that only some of this heterogeneity can be predicted using sociodemographic information. A substantial proportion of the heterogeneity at the individual level is unexplained, either because it is unobservable (inherited or acquired) or the result of measurement noise, even though we try to reduce the latter as much as possible by using a composite measure. Hence, we conclude that pension plan managers cannot predict pension plan members' risk preferences from sociodemographics alone: they also need to elicit the risk preferences directly from the members themselves to gain an accurate knowledge of them. By using our elicitation method, measurement noise is reduced, so that additional information on individual risk preference is revealed Alserda (2019). What the potential effects of this heterogeneity are

[5] In other fields of finance the use of composite scores to reduce noise is also quite common. For example: Bekaert et al. (2009) use principal component analysis to reduce country industry-level stock returns to three global and local factors and Baker and Wurgler (2006) use the first principal component of a number of noisy proxies for investor sentiment to create a sentiment index.

[6] Note that they also use a risk aversion coefficient of 5000 to show the limiting case with minimum risk.

Table 5
Explaining risk preferences with sociodemographics.

Variables	(1) MLC γ	(2) MLC γ	(3) Stated aversion	(4) Stated aversion	(5) Allocation to bonds	(6) Allocation to bonds	(7) Composite γ	(8) Composite γ
Constant	1.806***	−0.450	4.554***	5.252***	62.378***	101.633***	1.829***	2.284***
	(0.038)	(0.754)	(0.022)	(0.427)	(0.655)	(9.476)	(0.027)	(0.517)
Plan 2	0.119	0.007	0.163***	−0.045	1.741	−2.030	0.156**	−0.070
	(0.088)	(0.091)	(0.051)	(0.051)	(1.476)	(1.468)	(0.061)	(0.062)
Plan 3	0.595***	0.562***	0.057	−0.104*	2.742***	0.022	0.237***	0.058
	(0.099)	(0.102)	(0.058)	(0.058)	(1.033)	(1.040)	(0.069)	(0.070)
Plan 4	0.781***	0.472***	0.409***	0.035	5.288***	0.814	0.582***	0.125
	(0.135)	(0.153)	(0.078)	(0.087)	(1.305)	(1.519)	(0.094)	(0.105)
Plan 5	−0.168	−0.176	0.439***	0.385***	6.443***	5.728***	0.376***	0.311***
	(0.157)	(0.158)	(0.091)	(0.089)	(1.484)	(1.442)	(0.110)	(0.108)
Monthly income ($1,000)		−0.259***		−0.256***		−3.772***		−0.327***
		(0.077)		(0.044)		(0.988)		(0.053)
Monthly income^2 ($1,000)		0.019***		0.013***		0.206***		0.019***
		(0.006)		(0.003)		(0.079)		(0.004)
Age		0.114***		0.046**		−0.350		0.060***
		(0.032)		(0.018)		(0.402)		(0.022)
Age^2		−0.001***		−0.000***		0.003		−0.001***
		(0.000)		(0.000)		(0.004)		(0.000)
Male		−0.178*		−0.437***		−6.585***		−0.506***
		(0.091)		(0.051)		(1.105)		(0.062)
Has partner		0.114		0.107**		0.187		0.143**
		(0.091)		(0.052)		(1.141)		(0.063)
Owns house		−0.045		−0.214***		−3.648***		−0.202***
		(0.088)		(0.050)		(1.164)		(0.060)
Education 2		0.161		−0.339**		−6.413*		−0.248
		(0.259)		(0.147)		(3.760)		(0.178)
Education 3		0.083		−0.484***		−9.647***		−0.423**
		(0.257)		(0.146)		(3.724)		(0.176)
Education 4		0.314		−0.505***		−9.828**		−0.357*
		(0.270)		(0.153)		(3.874)		(0.185)
Education 5		0.158		−0.676***		−13.736***		−0.583***
		(0.265)		(0.150)		(3.802)		(0.181)
Education 6		−0.100		−1.011***		−21.392***		−1.020***
		(0.278)		(0.158)		(3.972)		(0.191)
Observations	7894	7894	7876	7876	3237	3237	7894	7894
R-squared	0.008	0.017	0.007	0.063	0.009	0.091	0.007	0.056

Notes: Results of regression analysis of observable characteristics on RRA. Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

on the asset allocation decisions of pension plan members remains to be seen. We evaluate this issue in Section 4.

Since we have three independent measures of risk aversion in the pension domain, we can further distinguish between measurement noise around true risk aversion that is fully determined by sociodemographics and heterogeneity in risk aversion beyond sociodemographics. To this end, we choose one risk aversion measure, normalize it, and regress it on the set of sociodemographic variables. The residuals retained from this regression are pure noise under the null hypothesis that sociodemographics fully determine risk aversion. Hence, a regression of these residuals on the average of the two other normalized risk aversion estimates should have a zero slope coefficient under the null. However, we find a slope coefficients that are significantly different from zero, regardless of which of the three risk measures we start out with orthogonalizing to our set of sociodemographic variables: 0.26, 0.65, and 0.57 (all significant at the 0.01 level) for starting with the MLC, stated aversion, and portfolio choice methods, respectively. The corresponding adjusted R^2 values are 0.06, 0.29, and 0.21, demonstrating that a substantial part of the variability is due to heterogeneity of risk aversion rather than measurement noise.

In addition to the strong result just discussed, four more detailed empirical analyses also indicate that combining elicitation methods into a composite score increases the reliability of the risk preference measure. First, the composite score has a correlation of −0.17 with investment experience, which we also asked about in the questionnaire, whereas this correlation is only −0.04 for the MLC question.[7] Second, the variation (standard deviation) of risk aversion is 30% lower for the composite score, which likely is due to reduced measurement noise. Third, the explanatory power (R^2) of sociodemographics is three times greater for the composite score than for the MLC method, expressed in terms of RRA. This result is consistent with previous research (e.g., Powell and Ansic, 1997; Jianakoplos and Bernasek, 1998), who find that these variables are relevant to risk preferences. Finally, 31% fewer members were found to be risk-seeking when the composite score was used. Since we do not expect many individuals to be risk seeking in the pension domain, this result is more in line with expected risk preferences in the pension domain.

4. Impact of risk preference heterogeneity on pension asset allocation

Viceira's (2001) life-cycle model shows that investors with 20 years to retirement should invest 100% of their financial wealth in stocks when their RRA coefficient equals three, whereas this percentage is 52% for a γ of five, and 28% for a γ of eight. Benzoni et al. (2007), who consider human capital and equity markets to be cointegrated, find that the optimal asset allocation is 100% stocks for an investor with 20 years to retirement and a risk

[7] Investment experience is not included in the regression with sociodemographics, since it is not directly observable to pension plan managers. Knowledge about investment experience requires some sort of elicitation.

aversion coefficient of three, around 60% for a risk aversion coefficient of four, and around 40% for a risk aversion coefficient of five. Although these are only two of many pension asset allocation models, it illustrates the importance of risk preferences. Therefore, if heterogeneity in risk preferences is greater, optimal pension asset allocations are likely to be more diverse, increasing the benefits of eliciting risk preferences.

Since we ask respondents about their risk preferences with regard to their total pension income, it is important to also include the social security pension income they expect to receive from the state. In the Netherlands, first pillar social security pension income is a fixed amount, irrespective of work history. Second pillar occupational pension schemes are typically defined as top-up on social security, such that a target pension is reached relative to one's average salary. Hence, for low-income workers, the second pillar pension comprises only a small amount of their total pension income. If we assume that social security pension is safe and therefore bond-like, the equity allocation of the relatively small occupational pension scheme can be 100%, even for risk-averse members. Since the first pillar is a fixed amount, the occupational pension will be more important for higher-income members. Heterogeneity in risk preferences therefore has a larger impact for members with higher a income. More generally, in countries with pension systems with no or little social security, information about risk preferences is more important for occupational pension scheme asset allocation.

The need for risk preference elicitation also depends on the expected equity premium. This intuition can be obtained from Merton (1969, p.251, eq.(29)), who shows that under certain restrictions the optimal allocation to risky assets equals the equity premium divided by the variance of the risky asset multiplied with the RRA coefficient. A low equity premium makes a portfolio of predominantly fixed income assets optimal for almost all risk preferences, whereas a high equity premium shifts the allocation toward equities for almost all risk preferences. Pension risk elicitation seems to be the most valuable for cases in between, where neither fixed income nor equities are dominant due to the expected equity premium.

4.1. The simulation model

Our aim in this section is to analyze the implications of risk preference heterogeneity on asset allocation. The large number of variables and time periods makes this optimization problem challenging to solve analytically. Therefore, we solve it numerically using a Monte Carlo simulation model (Dai and Singleton, 2002; Sangvinatsos and Wachter, 2005). This simulation model is built in the context of an individual DC pension scheme with investment during retirement. We do not simulate the existing CDC scheme because it contains the same asset allocation for each individual and we want to assess the welfare loss from this feature compared to one in which the asset allocation can differ across individuals. This choice of a constant asset allocation is motivated by the empirical observations on household portfolio choice of Ameriks and Zeldes (2004), who do not find support for traditional life cycle models with bond-like human capital in which the share of equities declines with age, as Bodie et al. (1992) does, or models with equity-like human capital, as Benzoni et al. (2007) do.

The asset return model is taken from Koijen et al. (2010). This model has been estimated by Draper (2012, 2014) with data relevant to the Netherlands. The estimated equity risk premium is replaced by the official regulatory equity risk premium in the Netherlands (Langejan et al., 2014). This model is also used by the Netherlands Bureau of Economic Policy Analysis (CPB). A complete description of the model and estimation procedure is given by Draper (2014).

The simulated asset returns are used to calculate total retirement income (before and after taxes) and occupational pension income (before taxes) separately over 10,000 scenarios for allocations of equity from 0% to 100%, in steps of 1%. This simulation is done for three ages, three (starting) incomes, and three equity premiums. All outputs are given in annual amounts denominated in U.S. dollars.

The main features of the members in our simulation model are as follows:

- For simplicity, during an individual's lifetime, we assume no real wage growth, a constant real first pillar pension,[8] and constant income tax brackets[9] in real terms. In other words, the growth in these quantities equals the inflation rate.
- During a member's working life, each year, 10% of the pension base (income minus deductible) is contributed as the pension premium. The capital accrues annually with the premium.
- Pension capital is invested with constant asset allocation over the life cycle (working life and retirement).
- The allocation to bonds is assumed to be invested in a portfolio of safe government bonds with the duration equal to the member's remaining investment horizon, capped at 30 years. If necessary, we use interpolated interest rates in between the available one, five, 10 and 30 year rates.
- For given income paths and asset returns, this approach leads to a second pillar pension capital w at retirement. At retirement, each year a fraction B of the pension capital w (the second-pillar benefit) is withdrawn, as follows:[10]

$$B = \frac{w * R_t}{1 - (1 + R_t)^{-L}} \quad (5)$$

  where R_t is the risk-free rate at time t and L is the expected remaining life expectancy in years.
- Total after-tax pension benefits are discounted with cumulative inflation to arrive at a net present value of the benefits.
- Pension plan members retire at the fixed age of 67 and pass away at the age of 85, for 18 years of pension benefits.
- To investigate the effects of the age of pension plan populations, our simulations start at different ages, such that the investment horizon differs. The amount of capital in our simulations that these older members start with is, for simplicity, the total premium increased by the risk-free rate from age 25.

4.2. Pension asset allocation

We calculate the average utility (Eq. (2)) that each asset allocation generates. The asset allocations for which the utility is highest are displayed in Table 6. The last columns show the results in the absence of social security or a state pension. This is, in principle, the case in countries such as Chile although, for most of these countries, means-tested or minimum pensions are offered by the state in case the private pension is not sufficient. To some extent, the government provides a put option that could potentially lead to excessive risk taking in pension portfolios. In our analyses, we abstract from these government-sponsored minimum pensions and assume that the private pension portfolio is the only source of income.

Our results in Table 6 show that heterogeneity in risk aversion leads to substantially different pension allocations, given our model settings. Since we do not allow for leverage

[8] Income in the first pillar is equal to $15,752.

[9] The progressive tax brackets are: less than $21,610 at 18.35%, $21,610-$36,911 at 24,10%, $36,911-$62,184 at 42.00% and above $62,184 at 54.00%.

[10] If $R_t = 0$, the equation is $B = w/L$.

Table 6
Optimal allocation of pension plan assets to equity.

(1)				(2)				(3)				(4)			
Income: $30.000				Income: $50.000				Income: $70.000				Without state pension			
γ	25	46	67	γ	25	46	67	γ	25	46	67	γ	25	46	67
0.0	100	100	100	0.0	100	100	100	0.0	100	100	100	0.0	100	100	100
0.5	100	100	100	0.5	100	100	100	0.5	100	100	100	0.5	100	100	100
1.0	100	100	100	1.0	100	100	100	1.0	100	100	100	1.0	100	100	100
1.5	100	100	100	1.5	100	100	100	1.5	100	100	100	1.5	100	100	100
2.0	100	100	100	2.0	100	100	100	2.0	100	100	100	2.0	83	78	78
2.5	100	100	100	2.5	100	100	100	2.5	100	100	100	2.5	69	64	62
3.0	100	100	100	3.0	100	100	100	3.0	99	97	99	3.0	59	55	52
3.5	100	100	100	3.5	100	100	100	3.5	91	89	88	3.5	52	47	44
4.0	100	100	100	4.0	95	95	98	4.0	85	82	78	4.0	46	42	39
4.5	100	100	100	4.5	90	89	90	4.5	79	76	71	4.5	42	38	34
5.0	100	100	100	5.0	86	84	83	5.0	74	71	65	5.0	38	34	31
5.5	100	100	100	5.5	82	79	77	5.5	70	66	59	5.5	35	31	28
6.0	100	100	100	6.0	78	75	72	6.0	67	62	55	6.0	33	29	26

Notes: Allocation to equity (in %) for different levels of (starting) income and in the case of no state pension. Results are given for different starting ages and different levels of RRA.

(i.e., allocations to equity financed with short positions in the risk-free asset) in the pension allocation, for γ coefficients of 1.5 and lower, we see that a 100% allocation to equities gives the highest utility, even in the absence of a state pension. This is the case for 42% of our respondents. With the presence of a state pension – which reduces the risk in the total pension income – more members should fully invest in equity. In total, our survey suggests that approximately 77% of our respondents should be fully allocated to equity.

The first part in Table 6 presents the optimal allocation when a state pension is included (e.g., the Netherlands). The state pension is assumed to be risk-free. The equity allocation is now 100% for γ coefficients below four (i.e., gross salary equal to $50,000). Traditionally, research on asset allocation has focused exclusively on the risk-bearing part of pensions, normally second-pillar occupational pensions (Viceira, 2001; Campbell et al., 2003). However, many countries have systems that include a risk-free state pension or social security (e.g., France, the Netherlands, the United States). The total pension amount relevant to individuals is the total retirement income, including both the risk-bearing pension and the state pension, all after taxes. This is the amount that individuals can use for consumption and that determines their standard of living, that is, utility. Other studies may ignore first pillar pensions, for example, because of their focus or relative insensitivity to it. However, our results show that we need to address the issue, since it has a major impact on outcomes. We are not aware of other pension asset allocation studies that explicitly take this issue into account. This is a novel aspect of our paper.

Table 6 also shows the differences with respect to income. This is important for our study on the Netherlands, since the state pension is a fixed nominal amount, independent of income. The impact of the state pension on the optimal asset allocation therefore depends on the member's income. For higher incomes, the relative importance of the state pension is reduced. For extremely large incomes, the state pension is so small that the optimal asset allocation is close to the case without a state pension. For lower incomes, the RRA coefficient is unimportant. For an employee with $30,000, the optimal asset allocation is 100% to equities for the range of RRA levels covered in Table 6. It is worth noting that, for income levels below the subsistence level, this effect could carry an additional risk, since utility can behave differently close to or below the subsistence level. In the case of the Netherlands, the state pension is above the nationally defined subsistence level; therefore, this effect is not relevant to our data. For other countries, however, it may be important to take the subsistence level into account when setting the asset allocation.[11]

4.3. How costly is having the "wrong" pension asset allocation?

In the previous sections, we showed that average pension risk aversion levels are close to two and that this implies an asset allocation of 100% to equities for a wide range of income levels when we take state pensions into account. Moreover, we also document a large amount of heterogeneity in risk aversion within pension plan populations, and that this heterogeneity is not attributable to sociodemographics. In this section, we investigate the welfare loss, given a single asset allocation for an entire pension plan population. To compute the welfare loss, we compare the pension plan allocation to the allocations in Table 6 that yield the highest EU. We realize that our concept of optimality only applies within the context of our model assumptions and, therefore, our welfare losses are also conditional on the assumption that our model and its parameters are correct. Therefore, this section is meant as an illustration rather than a definite answer to the far bigger question of how to determine an optimal pension asset allocation. The optimal allocation to equity and, thus, the value of eliciting risk preferences are conditional on the equity premium that we assume. In Appendix C, we conduct a sensitivity analysis to the equity premium and display optimal asset allocations for equity premiums that are 2% and 4% lower, which are closer to the estimated parameters of Draper (2014), which are lower than the regulatory parameters for the equity risk premium. Even though our model might not be fully correct, we note that the different pension asset allocation models estimated by Viceira (2001) and Benzoni et al. (2007) all show very different asset allocations for investors for different risk aversion levels, where higher risk aversion leads to lower allocations to equity. These are the most important features necessary to obtain results with a similar interpretation to ours.

We implement the concept of the certainty equivalent (Arrow and Lind, 2014) to determine, in monetary terms, how much value a pension scheme provides to an individual, given a specific pension asset allocation. The certainty equivalent transforms a distribution of uncertain outcomes into a single value with probability one that has the same utility. we can thus compare distributions of pension outcomes, where the differences represent

[11] In Appendix D we display the optimal asset allocation including income taxes.

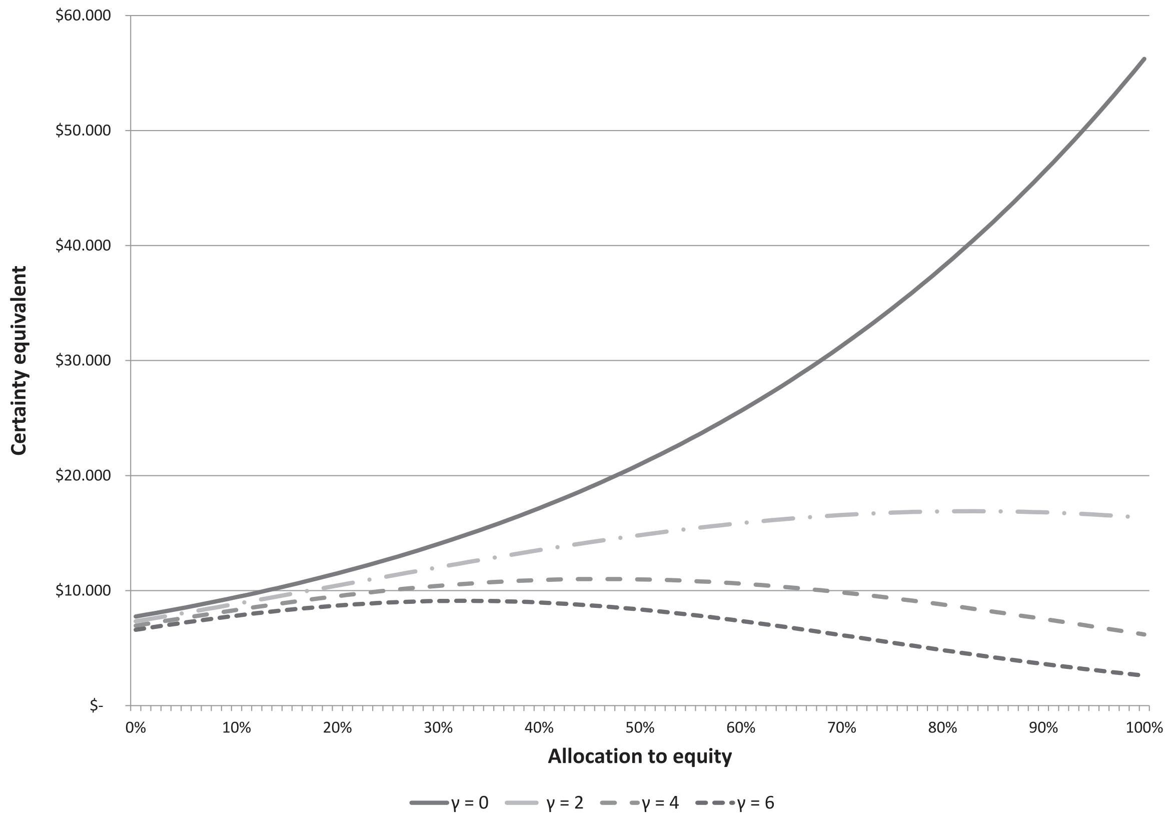


Fig. 2. Certainty equivalents.
Notes: Annual certainty equivalent plotted against allocation to equity for a member enrolling at age 25 with an annual income of $50,000, not taking the state pension and income taxes into account. The certainty equivalent is given for four levels of RRA. The certainty equivalent is highest (optimal allocation) for an allocation of 100%, 83%, 46%, and 33% for RRA (γ) levels 0, 2, 4, and 6, respectively.

utility levels equal to certain reductions in pension income. This approach allows us to determine the EU that is lost when an individual participates in a pension scheme with an exogenously determined uniform pension asset allocation. We use the following equation:

$$CE_i = (EU_i(1-\gamma_i))^{\frac{1}{1-\gamma_i}} \quad (6)$$

where CE_i is the certainty equivalent of the uncertain total pension income, EU_i is the EU of the total pension income, and γ_i is the (constant) RRA of individual i. This framework can be used to assess an individual's pension asset allocation.

Fig. 2 shows the certainty equivalents for a member who joins the pension plan at age 25 with an (initial) annual income of $50,000 for different levels of RRA, not taking the state pension into account. The graph shows that the expected annual value of pension income depends greatly on the chosen asset allocation. A risk-neutral ($r = 0$) individual will prefer the highest expected value, which is given by a 100% allocation to equity. When the pension plan invests instead 0% in equities, this implies a loss in certainty equivalent of $56,230–$7,750 = $48,480 each year. For a γ coefficient of six, the loss in certainty equivalent would be $6,500 when the pension plan invests 100% in equities, whereas the model-implied optimal allocation would be 33%.

Whereas Fig. 2 shows the certainty equivalents for four different γ coefficients and asset allocations, Table 7 shows the loss in certainty equivalent for different asset allocations and risk preferences compared to the optimal asset allocations. This is the loss that a member experiences from being forced into a given pension plan asset allocation that deviates from the member's personal optimal allocation. If we take γ equal to two from a given respondent at face value, the loss in certainty equivalent for a member in a pension plan with an allocation of 40% in equities is $7,655 per year, or, stated differently, about two month's salaries. Certainty equivalent losses are typically smaller for higher γ valus but typically still exceed one month's salary for each γ value when the member's desired and pension scheme's actual allocation are substantially different. Comparison of the welfare losses between the situation with and without a state pension (left and right panels, respectively, in Table 7) shows that including the state pension increases preferences for higher allocations to equity and, thereby, leads to larger welfare losses for lower allocations to equity for risk-averse individuals.

The analyses above are still somewhat hypothetical cases. Now, we turn to estimating the loss in certainty equivalents for each member given the actual asset allocation in the pension plan the member is participating in and taking into account the state pension in the Netherlands. Fig. 3 shows the loss in certainty equivalents (left axis) for members in the five company pension plans that participated in the survey, dependent on the risk preferences of the members. The certainty equivalents hold for a member who joins the pension plan at age 25 with an initial annual income of $50,000. The bars (right axis) present the total proportion of members in each of the respective ranges of γ. The results show that every asset allocation in our study is too safe given the preferences of pension plan members. This is due to the safe state pension, which induces even the most risk-averse members to favor more risk than is actually taken in the pension plans. This holds especially for the relatively large proportion of members who are risk-neutral or who have relatively little risk aversion.

Using the same method, we can classify the respondents of our survey into different groups, depending on age, income, pen-

Table 7
Loss in certainty equivalent.

Allocation to equity	Including state pension				Without state pension			
	$\gamma=0$	$\gamma=2$	$\gamma=4$	$\gamma=6$	$\gamma=0$	$\gamma=2$	$\gamma=4$	$\gamma=6$
0%	27,912	13,520	8344	5956	48,484	9573	4058	2525
10%	26,618	12,275	7145	4798	46,798	8052	2685	1,288
20%	25,046	10,853	5851	3615	44,726	6463	1488	414
30%	23,166	9285	4534	2502	42,182	4880	592	17
40%	21,008	7655	3291	1550	39,064	3389	90	142
50%	18,587	6044	2204	818	35,252	2081	29	753
60%	15,870	4509	1321	326	30,604	1041	404	1749
70%	12,785	3100	663	62	24,956	337	1163	2984
80%	9232	1858	235	3	18,118	18	2221	4283
90%	5054	815	27	116	9878	100	3475	5487
100%	0	0	20	367	0	577	4822	6498

Notes: Loss in certainty equivalent per year (in $) of different asset allocations and risk preferences compared to the optimal asset allocation. Values are given for a member aged 25 with initial annual income of $50,000. Left panel represents welfare loss in the situation with a state pension and progression income taxes. The right panel represents welfare loss in the situation without a state pension and income taxes.

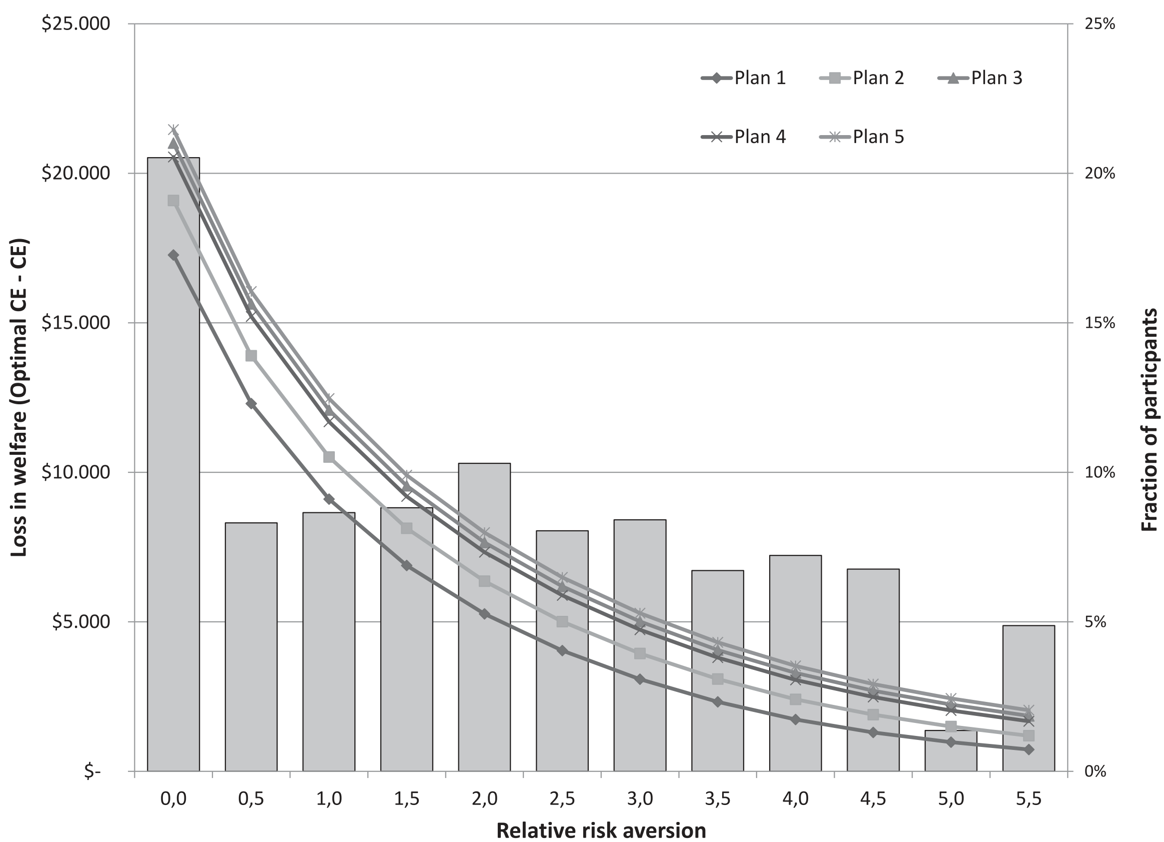


Fig. 3. Loss in certainty equivalent.
Notes: Loss in certainty equivalent (in $) for levels of RRA given asset allocation of the respective company pension plans (lines and left axis). Percentage of respondents with RRA, truncated at zero (bars and right axis). Certainty equivalents are given for a 25-year-old member, with initial annual income $50,000 and the state pension of The Netherlands.

sion plan, and risk aversion, and calculate the amount of welfare in certainty equivalents they lose by being forced into their pension plan's asset allocation. The sixth column of Table 8 shows the average welfare loss for the population for the five pension plans elicited with the current asset allocations. On average our survey respondents lose 13.76% of their optimal pension income welfare, about 1.5 to two month's pension income, from having a suboptimal asset allocation. These numbers range between 12.00% and 18.24% for different pension plans depending on the average income, age, risk aversion, asset allocation, and variation in risk aversion within the pension plan. For the sample as a whole the results equate to $47.5 million per year, or $6,019 per respondent per year, on average.

The welfare losses presented are driven by two factors: the fact that the asset allocation does not match the average risk preferences of the population and the fact that the collective optimal asset allocation is not equal to each individual's optimal asset allocation because of risk preference heterogeneity. In our empirical setting, much welfare is lost because the pension plans in our sample are too conservative for their members' risk preferences.

Table 8
Welfare losses per pension plan.

Pension plan	Current equity **allocation**	**Income** (month) Average	Age Average	Relative risk aversion Average	St. dev.	Welfare loss average Total	Collective	Individual
1	55%	$ 2537	50.1	1.829	1.918	13.25%	12.71%	0.54%
2	48%	$ 2097	53.8	1.985	2.009	12.00%	11.64%	0.36%
3	40%	$ 2168	44.8	2.066	1.724	18.12%	17.36%	0.76%
4	42%	$ 1813	52.2	2.411	1.651	12.47%	12.06%	0.41%
5	38%	$ 2498	48.5	2.205	1.861	18.24%	17.77%	0.47%
Total		$ 2396	50.1	1.926	1.901	13.76%	13.23%	0.53%

Notes: Welfare losses and sociodemographic information per pension plan with current asset allocations.

The fact that we can observe individuals' risk preferences helps improve the collective fit of the pension plans' asset allocations. By increasing the collective allocation to equity, welfare gains can be made without individualizing the asset allocation. The last three columns of Table 8 show the welfare losses for the current asset allocations compared to the case in which the asset allocation is set at the collective optimum of 100% equity. The penultimate last column (average 13.23%) shows the welfare loss from the first factor (collective suboptimal asset allocation across funds) and last column (average 0.53%) shows the welfare loss from the second factor (welfare loss through heterogeneity within a fund).

Based on our model specifications and data, total welfare for the five pension plans we study can be increased by $46.3 million per year, or $5,865 per respondent per year, on average, by setting the allocation at the collective optimum. The value of individualizing asset allocations can improve total welfare by an additional $1.2 million per year, equal to $154 per respondent. The value of eliciting risk preferences depends strongly on the assumed equity premium. With the default equity premium and a collective asset allocation, there is no value in eliciting risk preferences, since the optimal allocation for the average respondent ($\gamma = 1.926$) and the collective optimum are both an allocation of 100% to equity. In Section 5.2, we present the value of eliciting risk preferences for a number of different model assumptions.

An ordinary least squares regression with clustered standard errors shows the marginal effect of the measured RRA of the pension plan population and the current allocation to equity (each additional unit in the average γ is associated with a 0.23% lower allocation to equity). Average income appears to be a more important determinant of the asset allocation (a 10% higher average income is associated with a 1.0% higher allocation to equity). The effect of average γ on the asset allocation is larger for the composite score (−0.23%) than for the MLC results (−0.14%). Since there are only five observations of the asset allocation the statistical power (significance) of the regressions is low. The relation between the pension plan's average risk aversion and the allocation to equity is illustrated in Fig. 4. The figure shows that differences across members in pension domain risk preferences do appear to be a relevant determinant for pension plan managers' asset allocation decisions for the five pension plans that we study.

The simulations show that most of the welfare losses that we find are the result of an allocation to equity that is too low. The results demonstrate that, in the cases of the five pension plans that we study, pension plan managers can satisfy most members by increasing the asset allocation. Allocating (close to all) assets to equity (or other higher risk-categories) will increase the welfare of almost all members. However, while average welfare will increase in this case, many members will still face substantial welfare losses (see Table 8), since the collective asset allocation can never accommodate the heterogeneity in optimal asset allocations due to heterogeneous risk preferences.

5. Discussion

5.1. Implications for academic research

Our research has several implications for the academic research agenda on pension asset allocation. The use of unique data from 7894 members in five Dutch pension plans allows us to provide real-world empirical insight on the degree of explained as well as unexplained heterogeneity in pension plan members' risk preferences. The results confirm earlier findings that a large component of individuals' pension risk preference is idiosyncratic (e.g., due to unobserved individual or environmental factors (Grable et al., 2004; Cesarini et al., 2009)) and only knowable to investment managers after engaging in a dialog with the individual (i.e., preference elicitation). The levels of RRA that we find are substantially lower than is often assumed in papers discussing (optimal) asset allocation (e.g., Viceira, 2001; Campbell et al., 2003. However, the levels do correspond with the results of most papers eliciting financial risk preferences from individuals (e.g. Mankiw and Zeldes, 1991; Barsky et al., 1997; Holt and Laury, 2002). This implies a large gap between the risk preferences elicited from individuals and those used in setting asset allocations. A fruitful area for further research could be to better explain this gap. Perhaps this increased understanding will lead to questionnaires better suited to elicit pension risk aversion, change the way risk aversion can be incorporated in theoretical pension asset allocation models, or use the elicited risk preferences directly in existing pension asset allocation models.

These results together with simulation-based evaluations of the impact of risk preference heterogeneity also provide new theoretical (and real-world) insight into the contingent nature of optimal pension asset allocation. We highlight the importance of pension plan members' characteristics (i.e., time to retirement, income, and risk preference heterogeneity) and pension market conditions (i.e., the presence of a state pension) in determining an optimal pension asset allocation strategy. Future research could address other important contingencies and further investigate the interplay between risk preference heterogeneity and the environment in which this heterogeneity occurs in determining optimal asset allocation strategies.

The new augmented lottery choice method tailored to individual pension risk preference elicitation that we have developed provides a useful balance between a normative economic basis and individual-level specificity in risk preferences. Because the lottery choice questions are personalized to each individual's pension income based on current income and age (i.e., years to retirement), individuals could also directly take into account their personal situation. Augmentation with two other risk preference elicitation methods reduces the level of measurement error in the risk preference measure and improves robustness. Nevertheless, further research on methods to reduce measurement error in eliciting risk preferences could be warranted.

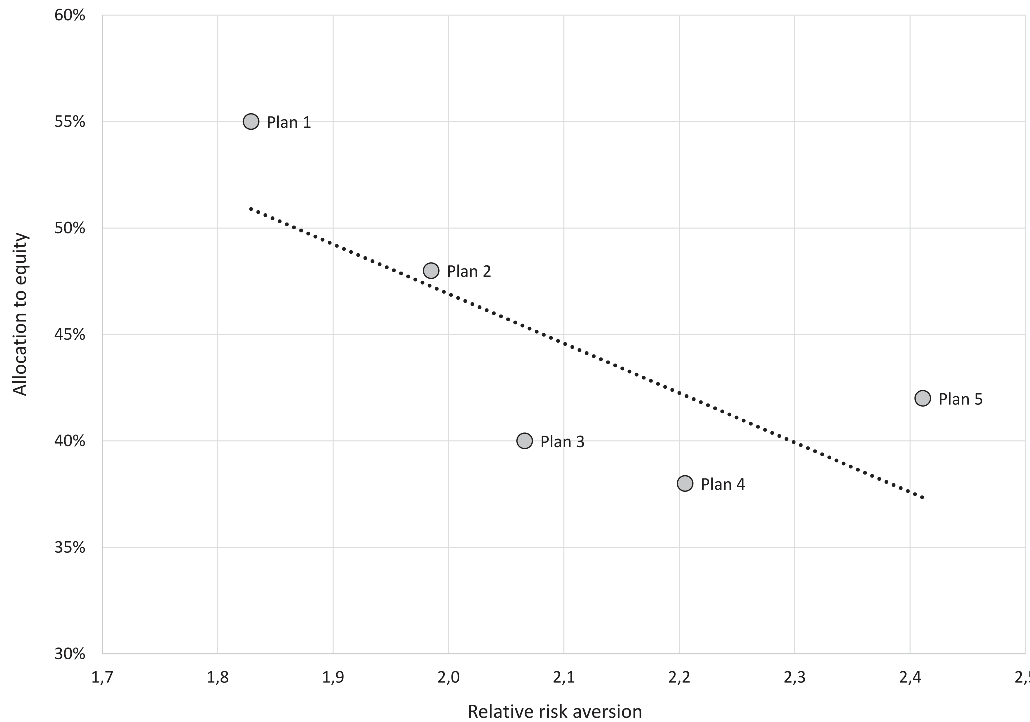


Fig. 4. Scatterplot of pension plans average risk aversion and allocation to equity.
Notes: Dotted line represents linear trend line.

Traditionally, the research on asset allocation has focused exclusively on the risk-bearing part of pensions, normally second-pillar occupational pensions (Viceira, 2001; Campbell et al., 2003). However, many countries have systems that include a risk-free first-pillar pension (e.g., France, the Netherlands, the United States), such as a state pension (e.g., social security). Our findings underline the importance of taking this context into account. They also provide a refinement of the conclusions of Bucciol and Miniaci (2015), in that we find that higher state pensions increase the allocation to equity in the optimal asset allocation of second pillar pension plans.

5.2. Managerial and policy implications

The value of eliciting risk preferences to set the optimal asset allocation depends on a number of contingency variables, which we summarize in Table 9 in a framework for pension plan managers. This table provides a qualitative overview of how the value of eliciting risk preferences depends on pension plan member characteristics and the pension market in which the plan operates.

Pension plans that have an older population, with many retired members, will find that the value of eliciting risk preferences is lower. The investment horizon is short, and therefore the effect of variations in asset allocation is lower. However, the value of eliciting risk preferences for the youngest members is also lower, since these member exhibit less heterogeneity in optimal asset allocations. Pension plans that service a population with relatively high incomes compared to their state pensions or those without a state pension (e.g., in countries such as Chile) directly affect a large proportion of individuals' retirement income. Therefore, the impact of asset allocation on members' retirement incomes is larger for these plans, which increases the value of eliciting risk preferences. In countries with relatively high state pensions (e.g., France), the value of risk preference elicitation is likely to be lower. Market conditions, especially equity premium, also influence the value of elicitation, because they affect the trade-off between equity and fixed income. With high equity premiums, equity becomes dominant and, since all members should (almost) fully invest in equity under these conditions, the value of elicitation is reduced. Finally, for pension plan populations with a greater risk preference heterogeneity (e.g., in industry-wide pension plans that combine many different types of plan members), the variation in optimal asset allocations is larger, which also makes the elicitation of risk preferences more valuable.

Table 7 shows that all of the pension plans in our sample have asset allocations that are too conservative for the vast majority of their members. This implies that, within our framework, pension plans can improve welfare by increasing the allocation to equity. However, since risk preferences are heterogeneous, a single asset allocation will always lead to the welfare losses of some of the members. To illustrate the framework with a numerical example, we assess the impact of risk preference heterogeneity for the case in which the asset allocation is matched to the average pension plan member.

Table 10 shows the value of customized individual asset allocation in a number of different situations compared to a strategy of optimizing for the mean level of risk preferences in our sample (i.e., $\gamma = 2$). This would be an alternative, simpler approach for pension funds compared to setting risk preferences; it matches the plan population average but accepts welfare losses due to heterogeneity in risk preferences. Hence, these results reflect the value of eliciting risk preferences and customized individual asset allocations.

Table 10 shows that the effect of time to retirement (age) is twofold. With longer periods to retirement the heterogeneity in optimal asset allocations is lower, which reduces the value of customized asset allocations. However, with shorter periods to retirement the impact of different asset allocations on pension benefits decreases, which also reduces the value of customized asset allocations.

With larger incomes, the relative size of the risk-bearing pension increases because the state pension is the same amount for

Table 9
Cost-benefit framework of eliciting risk preferences.

Contingency variable	Level of contingency variable: Low	High
Plan population		
Age	A young population should invest in equity anyway, so risk preferences are less relevant. However, due to the longer horizon differences become more pronounced	An old population may differ in terms of optimal asset allocation, however, due to a shorter period, the effect is less pronounced.
Heterogeneity	For a homogeneous population, elicitation may not be worth the while. A sample may suffice. Homogeneous populations may occur in niche industry-wide pension funds, or company pension funds.	Variety in risk preferences can make elicitation worthwhile. In large, widely defined industry-wide pension funds (e.g., civil servants), heterogeneity is likely to be large.
Pension market		
Income	State pension is paramount, so asset allocation is less relevant. This holds for low paid workers and/or in Beveridgean pension systems.	State pension is less relevant, so asset allocation, and therefore risk preferences, become more important. This holds for highly paid workers and/or in Bismarckian pension systems.
Equity premium	Large variety of optimal asset allocations, thus preferences are more important	Equity mostly optimal, so risk preferences are not relevant

Table 10
Value of eliciting risk preferences.

Variables	Maximum welfare loss				
Time to retirement (years)	**0**	**10**	**21**	**31**	**42**
	0.38%	0.62%	0.65%	0.40%	0.27%
Income (per year)	**$20,000**	**$30,000**	**$40,000**	**$50,000**	**$60,000**
	0.00%	0.10%	0.42%	0.69%	0.81%
Heterogeneity γ	**2.0–2.0**	**1.5–3.0**	**1.0–4.0**	**0.5–5.0**	**0.0–6.0**
	0.00%	0.01%	0.08%	0.28%	0.53%
Equity premium	**Default -4%**	**Default -3%**	**Default -2%**	**Default -1%**	**Default**
	2.22%	2.69%	2.11%	0.90%	0.53%

Notes: Average welfare loss as a ratio of total optimal pension income.

everybody. This increases the impact of different asset allocations but also increases the heterogeneity in optimal asset allocations. Therefore, higher incomes – or lower state pensions – increase the value of customized asset allocations.

In the absence of intraplan heterogeneity in risk preferences, there is no value in eliciting risk preferences. As risk preferences become more heterogeneous, optimal asset allocations become more heterogeneous, and the value of eliciting risk preferences increases. Finally, with higher equity premiums the heterogeneity in optimal asset allocations decreases, as more members prefer full equity allocations. Therefore lower equity premiums, with more heterogeneous asset allocations, lead to more valuable risk preference elicitations and asset allocation customizations. When the equity premium is very low or absent, most members will prefer no risk taking and the value of eliciting risk preferences decreases again. Including ambiguity aversion in our analyses would have similar effects on asset allocation as having a lower equity premium. Therefore, if real-life pension asset allocation is better described by a combination of risk and ambiguity aversion, this would likely lead to effects similar to those of using a lower equity premium in the current model.

5.3. Limitations and further research

Several limitations and potentially fruitful extensions of our research are worth noting. Our results are based on cross sectional data. With panel data, more research and management questions could be answered. Future research could shed more light on the time dependency of risk preferences. This work is relevant to pension plan management as well, because such time dependency influences the frequency of conducting risk preference surveys among plan members. For instance, if risk preferences change due to large events, such as the 2008 financial crisis, surveys need to be repeated every couple of years. If the risk preferences of individuals are stable, then a new survey is warranted only if the plan population changes substantially. Since risk preference surveys are costly for the pension fund, such considerations are material.

We explicitly model pension members' normative risk preferences using EU with constant RRA. Normative risk preferences can deviate from revealed risk preferences due to well-known measurement irregularities, such as probability weighting, loss or disappointment aversion, and the reflection effect. The elicitation methods are selected to minimize measurement bias, but we do not adjust the results in order to address potential behavioral effects. To explain the revealed preferences, other utility functions can be used, including behavioral effects such as loss or disappointment aversion. We leave the impact of applying such more behavioral models on optimal pension asset allocation to future research.

Our analysis is set in an individual pension asset allocation setting with constant asset allocations. Although this setting yields the clearest theoretical insights, some adjustment is necessary to allow the results to be applied to individual pension plans with life-cycle options and to collective pension plans. Additionally, adding more asset categories and financial derivatives or variable annuities (Mahayni and Schneider, 2012) would yield more complete insight.

Individual pension plans, such as DC plans, often allow members to invest in line with a life-cycle model. Life-cycle models

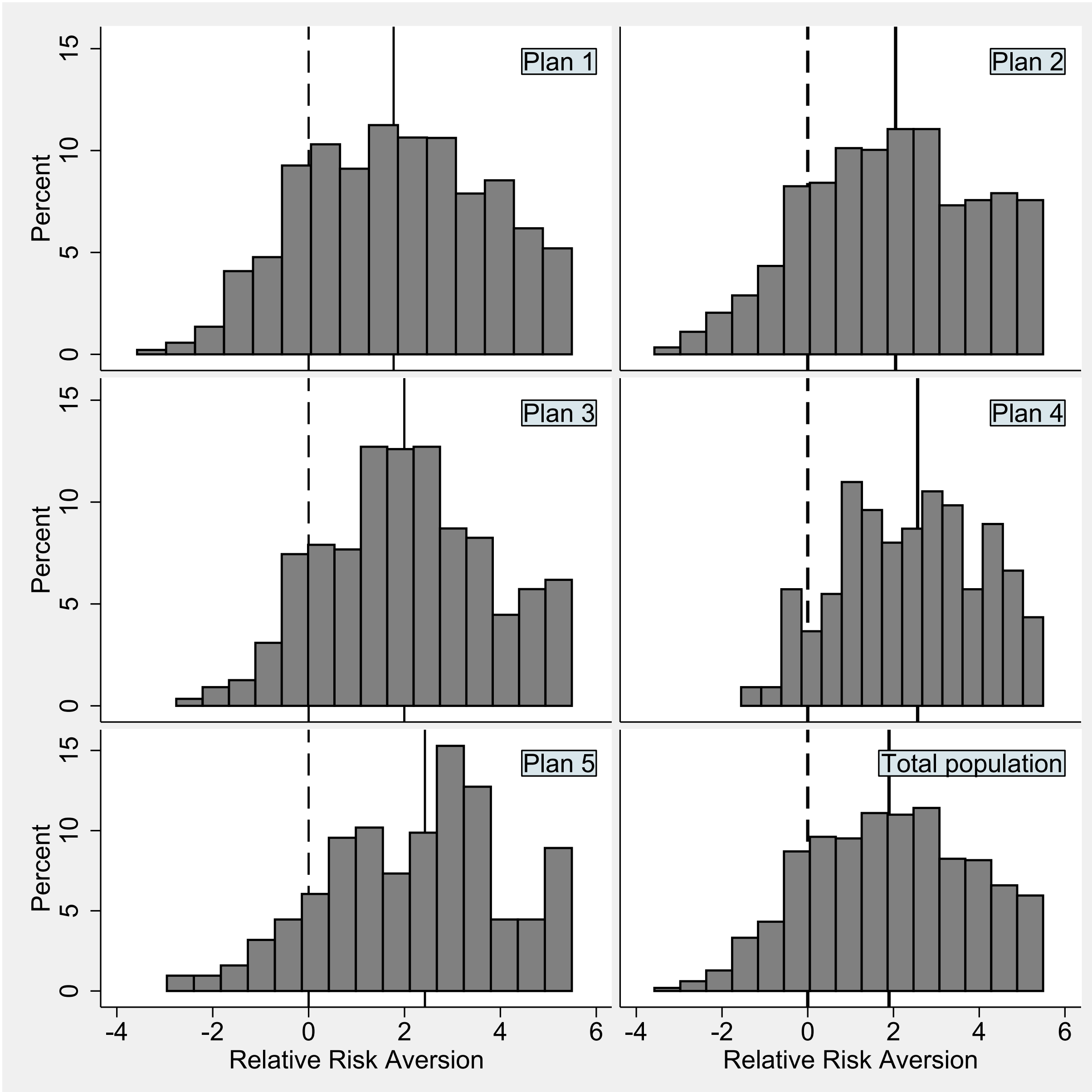


Fig. 5. Histograms of relative risk aversion.
Notes: Results are given for plans 1 to 5, respectively, and total population. The dashed line represents risk neutrality and the solid line represents the population's median RRA score.

Table 11
Allocation to equity with equity premium: default - 2%.

(1)				(2)				(3)				(4)			
Income: $30.000				Income: $50.000				Income: $70.000				Without state pension			
γ	25	46	67	γ	25	46	67	γ	25	46	67	γ	25	46	67
0.0	100	100	100	0.0	100	100	100	0.0	100	100	100	0.0	100	100	100
0.5	100	100	100	0.5	100	100	100	0.5	100	100	100	0.5	100	100	100
1.0	100	100	100	1.0	100	100	100	1.0	100	100	100	1.0	98	97	100
1.5	100	100	100	1.5	100	100	100	1.5	100	100	100	1.5	72	69	70
2.0	100	100	100	2.0	100	100	100	2.0	91	91	94	2.0	57	54	52
2.5	100	100	100	2.5	92	92	99	2.5	81	80	79	2.5	48	44	42
3.0	100	100	100	3.0	82	84	87	3.0	74	71	68	3.0	41	37	35
3.5	100	100	100	3.5	79	77	78	3.5	68	64	60	3.5	36	32	30
4.0	100	100	100	4.0	74	71	70	4.0	62	59	53	4.0	32	29	26
4.5	100	100	100	4.5	69	67	64	4.5	58	54	48	4.5	29	26	23
5.0	98	100	100	5.0	65	62	59	5.0	54	51	44	5.0	26	23	21
5.5	95	96	100	5.5	62	59	54	5.5	51	47	40	5.5	24	22	19
6.0	92	93	100	6.0	59	56	50	6.0	48	44	37	6.0	23	20	17

Notes: Allocation to equity (in %) for different levels of (starting) income and in the case of no state pension. Results are given for different starting ages and different levels of RRA.

Table 12
Allocation to equity with equity premium: default - 4%.

(1)				(2)				(3)				(4)			
Income: $30.000				Income: $50.000				Income: $70.000				Without state pension			
γ	25	46	67	γ	25	46	67	γ	25	46	67	γ	25	46	67
0.0	100	100	100	0.0	100	100	100	0.0	100	100	100	0.0	100	100	100
0.5	100	100	100	0.5	100	100	100	0.5	100	100	100	0.5	89	93	100
1.0	100	100	100	1.0	87	91	100	1.0	77	78	86	1.0	55	53	57
1.5	100	100	100	1.5	75	76	85	1.5	64	63	65	1.5	40	38	38
2.0	96	100	100	2.0	66	66	70	2.0	56	54	52	2.0	32	29	28
2.5	89	93	100	2.5	59	58	60	2.5	49	47	43	2.5	26	24	22
3.0	84	86	100	3.0	54	52	52	3.0	44	42	37	3.0	23	20	19
3.5	79	81	94	3.5	50	47	46	3.5	40	38	33	3.5	20	18	16
4.0	95	76	86	4.0	46	43	41	4.0	37	34	29	4.0	18	16	14
4.5	72	72	80	4.5	43	40	37	4.5	34	32	26	4.5	16	14	12
5.0	69	69	74	5.0	40	37	34	5.0	32	29	24	5.0	15	13	11
5.5	66	65	69	5.5	38	35	31	5.5	30	27	22	5.5	14	12	10
6.0	63	62	65	6.0	35	33	28	6.0	28	26	20	6.0	13	11	9

Notes: Allocation to equity (in %) for different levels of (starting) income and in the case of no state pension. Results are given for different starting ages and different levels of RRA.

Table 13
Optimal allocation of pension assets to equity.

(1)				(2)				(3)			
Pension without state pension before taxes				Pension with state pension before taxes				Pension with state pension after taxes			
γ	25	46	67	γ	25	46	67	γ	25	46	67
0.0	100	100	100	0.0	100	100	100	0.0	100	100	100
0.5	100	100	100	0.5	100	100	100	0.5	100	100	100
1.0	100	100	100	1.0	100	100	100	1.0	100	100	100
1.5	100	100	100	1.5	100	100	100	1.5	100	100	100
2.0	83	78	78	2.0	100	100	100	2.0	100	100	100
2.5	69	64	62	2.5	100	100	100	2.5	100	100	100
3.0	59	55	52	3.0	100	100	100	3.0	100	100	100
3.5	52	47	44	3.5	98	98	100	3.5	100	100	100
4.0	46	42	39	4.0	92	91	94	4.0	95	95	98
4.5	42	38	34	4.5	87	85	85	4.5	90	89	90
5.0	38	34	31	5.0	82	80	78	5.0	86	84	83
5.5	35	31	28	5.5	78	76	72	5.5	82	79	77
6.0	33	29	26	6.0	75	72	67	6.0	78	75	72

Notes: Optimal allocation to equity (in %) in the case of no state pension and income taxes, in the case of a state pension and no income taxes, and in the case of a state pension and income taxes. Results are given for different starting ages and levels of RRA. Starting income fixed at $50,000.

adapt asset allocations to investor age. Individuals farther from retirement are assigned a high allocation to equity and, as the time horizon declines, allocation to equity decreases. This mechanism is designed to compensate for the stronger effect of equity on the riskiness of the final pension income in shorter investment horizons or, defined differently, this shift is due to the decline in human capital compared to financial capital (i.e., where human capital acts as a diversification mechanism) (Viceira, 2001). This is in line with our finding that pension members who start later have lower optimal allocations to equity. Since life-cycles can be used to decrease the effect of risk on pension income, equity may be even more desirable when life-cycle timing is allowed. Adding life-cycles to our model would be an interesting avenue for further research.

In addition, in some countries, members in individual pension plans are obligated to convert (part of their) pension capital to annuities on the retirement date. This reduces the amount of risk that retirees can take and leads to significant welfare losses according to our model (i.e., due to the positive allocation to equity for 67-year-olds). Such a policy influences optimal asset allocation and will presumably transfer risk from the retirement phase to the active phase. Such policies also add additional interest rate risk for members, who become highly sensitive to the interest rate on the day of conversion (normally the retirement date). Adding both these mechanisms to the model would increase its practical usability; however, optimizing this model in this way would be computationally demanding given the very large number of resulting possibilities.

Collective pension plans generally provide only a single asset allocation for all their members. As our results show, the heterogeneity in risk preferences and sociodemographic characteristics makes the single asset allocation suboptimal for many members, who will face welfare losses. Another difference in collective pension plans is the possibility of employing intergenerational risk sharing (Chen et al., 2016). Employing intergenerational risk sharing reduces risk through longer time diversification. Further research could reveal whether the benefits of collective schemes, such as intergenerational risk sharing, outweigh the welfare losses that result from the mismatch between a homogeneous asset allocation and heterogeneous risk preferences.

In the case of collective pension plans with a single asset allocation, the question becomes how to use risk preferences in determining the single asset allocation. By definition, single asset allocation results in welfare losses when risk preferences are heterogeneous. Choosing the asset allocation that minimizes aggregated welfare losses could be one option to cope with this problem; however, that would weight higher incomes more heavily, which could be considered socially undesirable. Other options include weighting the optimal individual asset allocations with the number of members or accumulated benefits. Each choice weighs specific income and age groups individually; the choice mainly depends on pension plan–specific preferences.

Further, our results show a large discrepancy between optimal asset allocation and the current asset allocations of the pension plans studied (Fig. 3). Several factors could explain this, in addition to previously mentioned points. First, the horizons of pension plan managers and regulators are far shorter than those of most members. Legislation often requires pension plan managers to focus on short-term (under 10 years) nominal performance measures, such as the coverage rate and pension cuts. The members (in our model) value only actual pension benefits. Members are thus, more often than not, assumed to have a horizon exceeding 20 years. This mismatch could implicitly lead to myopic loss aversion (Benartzi and Thaler, 1995); by reducing year-to-year volatility, long-run volatility may be suboptimal. Second, the interests of other stakeholders, such as the sponsoring company, supervisors, and politicians, could influence asset allocation. However, since pension members are the primary stakeholders of pension plans, integrating their long-term preferences more strongly into the decision process of the (collective) asset allocation could substantially increase their welfare.

We hope that our research can provide a fruitful next step in developing insights into when and how to elicit pension plan member risk preferences to make more informed decisions about how to match members' risk preferences with pension plan investment allocations.

6. Conclusion

This study measures risk preferences in the pension domain of 7894 members in five Dutch pension plans, using an augmented version of the MLC method via an online survey. By combining data from multiple risk preference elicitation methods in a composite score, we assign personal values of RRA to the members in these pension plans and overcome several difficulties related to individual measures of risk preference (i.e., dominated choices and measurement noise).

Our results show great heterogeneity in pension income risk preferences. Risk preferences tend to vary both within the population of a pension plan and between the populations of different pension plans, in both the level and variation of risk preferences. Variation between pension plan populations is mainly driven by differences in sociodemographic characteristics, such as age, gender, and income and, to a lesser extent, by potential selection effects of specific industries or employers. Sociodemographic information and pension plan membership account for only 5.6% of the variation, so the modeling of risk preferences with observable sociodemographic information cannot replace the measurement of individual risk preferences.

Our simulation quantifies the importance of risk preferences for optimal asset allocation. Allocation to equity in the optimal asset allocation changes by up to 30% in our baseline model. Inclusion of the state's old age pension substantially increases the allocation to equity, since it increases the security of the total retirement income. Other variables that influence optimal asset allocation (given risk preferences) are income (via the relative size of the state's old age pension), age, and the equity premium.

Further, suboptimal asset allocation leads to significant welfare losses to pension plan members. With our model assumptions the respondents of our survey lose, on average, 13.76% of their pension welfare by being forced into a suboptimal asset allocation, given their personal preferences and situations. Increasing the level of the collective asset allocation to the collective optimum can increase welfare by 13.23%. The remaining 0.53% can only be achieved by allowing members to customize their asset allocation to their personal risk preferences.

Finally, the value of eliciting risk preferences and customizable pension asset allocations depend on a number of pension plan characteristics and market expectations. First, higher levels of income, compared to the state pension, increase the effect of asset allocation on total pension income and therefore increase the value of elicitation. Second, both lower equity premiums and greater heterogeneity in risk preference increase the variance of optimal asset allocations and the value of elicitation. Finally, age influences the value of elicitation through the investment horizon. Shorter periods to retirement cause more variation in optimal asset allocations; however, as the investment period becomes shorter, differences due to asset allocation become less pronounced.

Appendix A. The pension system in the Netherlands

Our online survey is conducted by five pension funds that operate in the Netherlands. In this appendix, we describe the essential features of the pension system in the Netherlands and compare it with the pension system in the United States where appropriate.[12] This should clarify the context of the members in our survey, and indicate how our empirical results can be used by pension funds, regulators, and other stakeholders.

The three pillars of the pension system are organized as follows. The first pillar consists of social security pensions organized by the government and are primarily pay-as-you-go financed. The pension is different for one- and two-person households but, otherwise, each inhabitant receives a fixed amount, irrespective of working history. This amount should cover essential expenses and should prevent extreme poverty among the elderly. The second pillar is work related, voluntarily organized by a company or industry, and required to be capital financed by law. Participation is semi-mandatory if employed by a company or industry with a pension plan, which means that most Dutch employees are covered by a second pillar pension plan. The five pension funds that participated in our online survey offer these second pillar pension plans. In the third pillar, an individual may set up an individual pension savings or investment account with a bank or insurance company. In the United States, this is often referred to as an individual retirement account. The average replacement rate in 2012 was estimated by Statistics Netherlands (CBS) to be 39% from the first pillar and 30% from the second pillar.

The second pillar pension plan is part of the negotiations between employer and employees. This means that it can range from a traditional defined benefit (DB) scheme, in which the employer bears all the risks related to the final- or average-wage pension that is promised, to a defined contribution (DC) scheme, with investment choices and/or contribution rates delegated by the individual. In the United States, many civil servants seem to be part of a DB pension plan, whereas corporate plans these days are mostly DC plans, among which 401(k) plans have become popular. However, as Ponds and Van Riel (2009) indicate, most pension plans in the Netherlands contain risk-sharing elements between the employer(s) and employees, which is uncommon in the United States. Moreover, over the past decades, the amount of risk borne by the employee has increased considerably. These risk-sharing agreements can consist of several elements. First, most pension plans make cost-of-living adjustments to accrued payments (inflation compensation), unless the pension plan is not sufficiently funded. Second, when underfunding is severe and prolonged, nominal pension benefits can also be reduced. This effectively means

[12] For more detailed information, see the report by the Dutch Association of Industry-wide Pension Funds titled "The Dutch Pension System: An Overview of the Key Aspects."

that the contributions from the employer(s) to the pension plan are capped, which makes corporate pension expenses more predictable and less procyclical. In case corporate pension plan contributions are fixed for a period of at least five years, they can be considered DC plans according to International Financial Reporting Standards. Industry-wide pension plans are considered to be collective DC plans, unless the deficits in the pension plan can be easily attributed to an employer (DB). This means that, even though the term career-average pension plans suggests a DB, their risk-sharing arrangements make them closer to DC plans. Note that excess funding is typically kept as a financial reserve for future generations to reduce volatility in pension outcomes between generations.

Pension funds are governed by a board of trustees that should make sure that the pension plan is fair for all stakeholders. To ensure this, at most half of the board of trustees can be appointed by the employer(s), while the others are appointed by the employees or retirees. The strategic pension plan asset allocation is set by the board of trustees, where pension contributions by employer and employees are traded off against pension outcomes. This trade-off takes both the level and variations around this level into account. For the pension outcomes, the possibility of cost-of-living adjustments are considered, as well as possible nominal pension reductions. Note that, if the second pillar offered classic DB pension plans, that is, plans in which all the investment and longevity risk is borne by an employer that cannot default on its pension promise, our analysis on individual risk preferences in the pension domain would not be necessary. In such a case, only the employer's risk preferences would matter, since the members' retirement income would be risk free.

Appendix B. Individual method responses (Fig. 5)

Appendix C. Effect of the equity premium on optimal asset allocation

The equity premium largely determines the benefits of holding equity. Higher equity premiums make equity more attractive and normally lead to higher (optimal) allocations to equity. Tables 11 and 12 show the optimal asset allocation for different levels of the equity premium. Table 11 shows the allocation with a 2% reduction in the equity premium that follows from historical data. In this case the benefits of measuring risk preferences increase, since the allocation to equity declines and, therefore heterogeneity in optimal asset allocations increases. Additionally, measuring risk preferences can substantially decrease allocation mismatches and the welfare losses resulting therefrom. Finally, Table 12 presents the optimal allocation in the case of a pessimistic equity premium of that is 4% reduced compared to the default equity premium. The heterogeneity in optimal asset allocations is the highest in this case.

Appendix D. Effect of the state pension and taxes on optimal asset allocation

Two variables that influence retirement income are the presence of a state pension and taxes in a pension system. A state pension, such as social security, creates a risk-free minimum, which reduces the riskiness of the total pension income. Therefore, given total pension risk preferences, members will want to increase the riskiness (i.e., allocation to equity) of the risk-bearing pension in the presence of a state pension. Taxes reduce the amount of the total pension income. Depending on the kind of system, taxation can result in divergent pension amount outcomes. Progressive systems will (on average) tax higher pensions more than they will tax lower pensions. This will theoretically influence the costs and benefits of risk and, therefore, asset allocation.

Column (1) of Table 13 presents the optimal asset allocation in the case without a state pension or income taxes. Column (2) presents the optimal asset allocation given a state pension (Dutch old age state pension) and no income taxes and, finally, Column (3) presents the optimal asset allocation with the same state pension and income taxes (Dutch progressive taxes). The results show that the presence of a state pension substantially increases the allocation to equity, by up to 56%. Income taxes, on the other hand, have only minimal effects. In the presence of income taxes, the allocation to equity increases by a maximum of 5%. Progressive income taxes thus have a (limited) risk-reducing effect.

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