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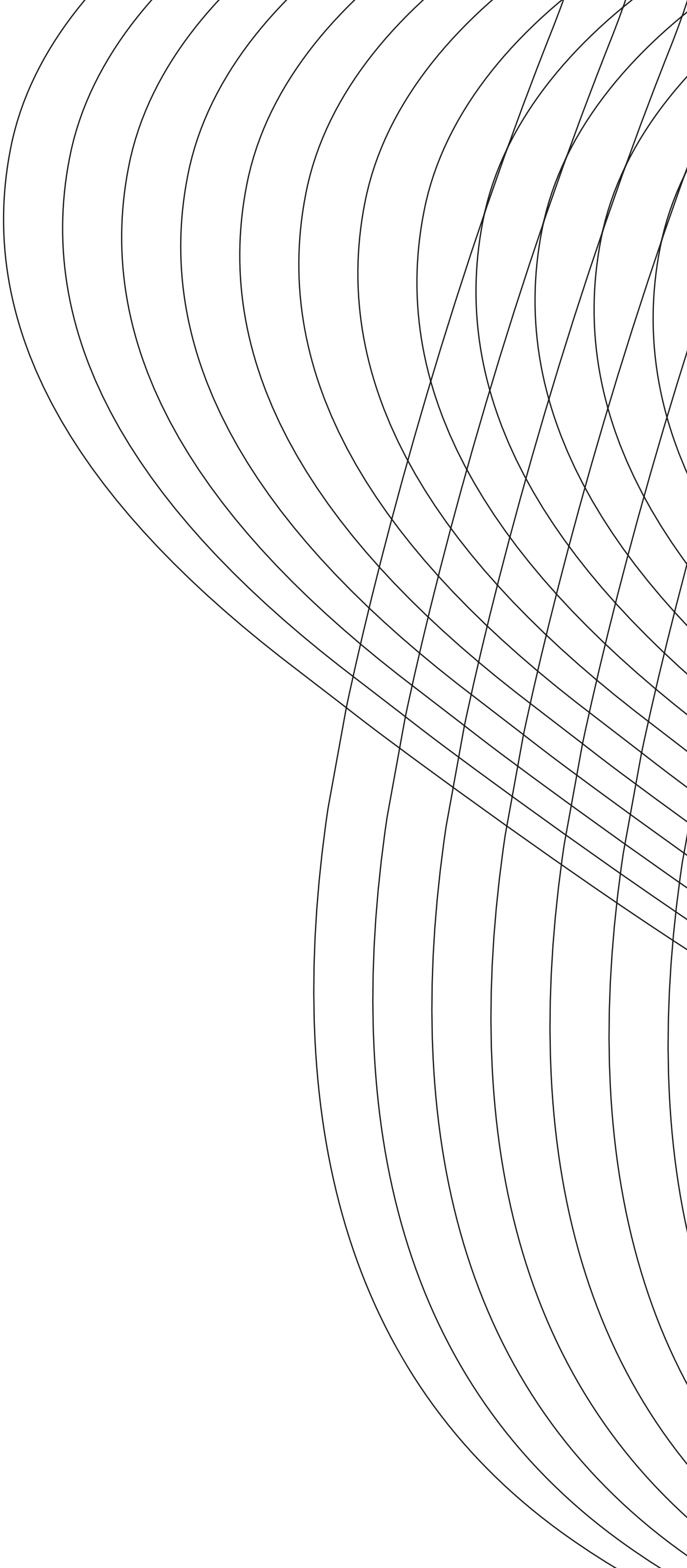
Network for Studies on Pensions, Aging and Retirement

Netspar DESIGN PAPERS

Bas Donkers, Carlos Lourenço, Daniel Goldstein and Benedict Dellaert

Building a distribution builder

Design considerations for financial investment and pension decisions



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Editorial address
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PO Box 90153, 5000 LE Tilburg
info@netspar.nl

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PREFACE

Netspar seeks to stimulate debate on the effects of aging on the behavior of men and women, (such as what and how they save), on the sustainability of their pensions, and on government policy. The baby boom generation is approaching retirement age, so the number of people aged 65 and over will grow fast in the coming decades. People generally lead healthier lives and grow older, families have fewer children. Aging is often viewed in a bad light since the number of people over 65 years old may well double compared to the population between 20 and 65. Will the working population still be able to earn what is needed to accommodate a growing number of retirees? Must people make more hours during their working career and retire at a later age? Or should pensions be cut or premiums increased in order to keep retirement benefits affordable? Should people be encouraged to take personal initiative to ensure an adequate pension? And what is the role of employers' and workers' organizations in arranging a collective pension? Are people able to and prepared to personally invest for their retirement money, or do they rather leave that to pension funds? Who do pension fund assets actually belong to? And how can a level playing field for pension funds and insurers be defined? How can the solidarity principle and individual wishes be reconciled? But most of all, how can the benefits of longer and healthier lives be used to ensure a happier and affluent society? For many reasons there is need for a debate on the consequences of aging. We do not always know the exact consequences of aging. And the consequences that are nonetheless clear deserve

to be made known to a larger public. More important of course is that many of the choices that must be made have a political dimension, and that calls for a serious debate. After all, in the public spectrum these are very relevant and topical subjects that young and old people are literally confronted with.
For these reasons Netspar has initiated Design Papers. What a Netspar Design Paper does is to analyze an element or aspect of a pension product or pension system. That may include investment policy, the shaping of the payment process, dealing with the uncertainties of life expectancy, use of the personal home for one's retirement provision, communication with pension scheme members, the options menu for members, governance models, supervision models, the balance between capital funding and pay-as-you-go, a flexible job market for older workers, and the pension needs of a heterogeneous population. A Netspar Design Paper analyzes the purpose of a product or an aspect of the pension system, and it investigates possibilities of improving the way they function. Netspar Design Papers focus in particular on specialists in the sector who are responsible for the design of the component.

Roel Beetsma
Chairman of the Netspar Editorial Board

Affiliations

Bas Donkers – Erasmus University Rotterdam
Carlos Lourenço – Erasmus University Rotterdam
Daniel Goldstein – Microsoft Research and
London Business School
Benedict Dellaert – Erasmus University Rotterdam

BUILDING A DISTRIBUTION BUILDER

Introduction

Recent research suggests that advice and communication about investment risks can be improved by use of the Distribution Builder (Goldstein, Johnson, and Sharpe 2008). Essentially, this is an interactive tool that allows consumers to engage in a hypothetical investment task and to experience risk-return tradeoffs. The objective of this paper is to provide an overview of design considerations when developing a Distribution Builder that is intended to measure two main characteristics of the risk profile of consumers: the utility function (how outcomes are valued by consumers) and the probability weighting function (the extent to which consumer perceptions of probabilities are biased). We focus on the domain of financial investments, in particular those related to pension funds.

In the first section of the paper we offer an intuitive overview of the basic structure of the Distribution Builder and of its main components. We explain risk-return tradeoffs for a lay audience and show how they are presented within the Distribution Builder. This section is enriched with several graphical print screens. These allow visualization of the actual Distribution Builder environment that individuals use on a computer interface and illustrate how the tool works in practice.

The second and third sections describe the insights into the decision-making process that can be gained from preferred outcome distributions. They also describe the financial algorithms and resulting state prices underlying the budget calculations that make the Distribution Builder work. In these rather technical sections we first describe formally the decision problem underlying a typical Distribution Builder task and how this task can be used to elicit the value function and the probability weighting function, which are the key components in a model of rank-dependent utility (e.g. prospect theory by Tversky and Kahneman 1992). Furthermore, we discuss the requirements for model identification and go into some detail about how existing financial market data can be used to construct the risk-return payoffs in the distribution builder.

In the fourth section, we discuss "choice architecture" and implementation of the decision tool, focusing on different presentation formats and their implications for user interaction. We discuss the implications of using "experienced probabilities" as a means of communicating with users and stress the advantages of this format over "probabilities from description", which have been used in most academic studies to date (Gigerenzer et al. 2005; Hoffrage and Gigerenzer 1998). To better illustrate this, we again use graphical print screens of the actual Distribution Builder environment on a computer interface.
In the fifth section, we discuss the potential use of the Distribution Builder in the domain of pension funds and retirement savings – a pressing domain in Western economies with their rapidly aging populations. Furthermore, we argue for the use of the Distribution Builder in the financial *advice* industry in general, especially in light of the recent financial crisis that showed a lack of transparency in the market for retail derivatives. Moreover, investment decisions are typically made on the basis of limited knowledge, so much so that many investors were not even aware of credit risk before Lehman Brothers and other major financial firms filed for bankruptcy (Wallmeier 2011). As such,

standard communication practices in financial services are limited to explaining contract designs, illustrating payoff diagrams, and presenting value-at-risk measures, thus leaving ample room for improvement. Based on solid psychological and financial foundations, the Distribution Builder meets these calls for better means of communication and advice about risks for investors.[1]

We conclude with final remarks on the promise of the Distribution Builder and similar tools in the financial industry and on important future research questions that can enhance our theoretical understanding of decision-making under uncertainty.

1 As noted by Wallmeier (2011), characteristics of return distributions such as skewness and kurtosis can be evaluated only when taking the related risk premiums into account, thus requiring a market equilibrium analysis.

1. The basic structure of a Distribution Builder

The Distribution Builder draws on previous research on risk representations that demonstrate that individuals are best capable of understanding probabilities when given a graphical

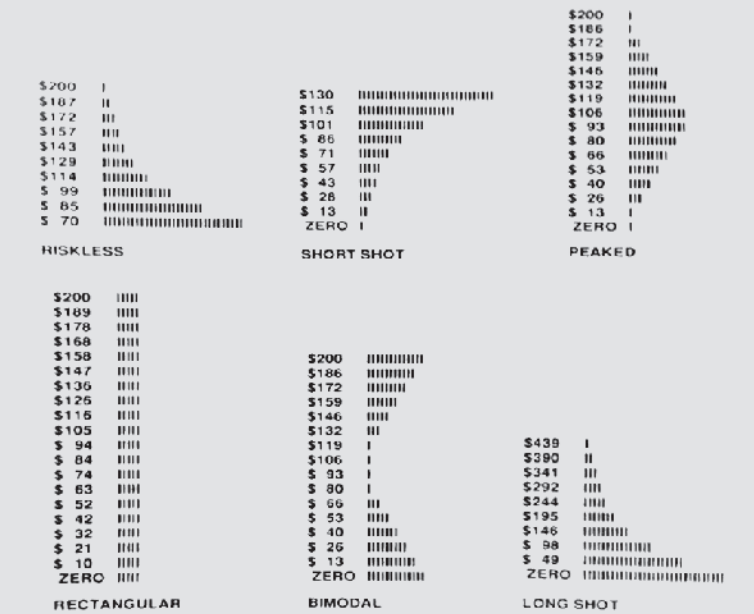


Fig. 2. Examples of stimulus lotteries for gains. Each lottery has 100 tickets (represented by tally marks) and each has an expected value of approximately $100. The values at the left give the prizes that are won by tickets in that row. The lotteries are ordered from the upper left to the lower right in the order that they are preferred by risk-averse subjects.

Figure 1. Examples of frequency lotteries in Lopes and Casey (1986)

"Each lottery has 100 tickets (represented by tally marks) and each has an expected value of approximately $100. The values at the left give the prizes that are won by tickets in that row. The lotteries are ordered from the upper left to the lower right in the order that they are preferred by risk-averse subjects." (cf. Lopes 1987). Risk as a function of shape has been proposed by Luce (1980), Pollatsek and Tversky (1970), Allais (1979), Coombs (1975), Hagen (1969), and Markowitz (1959) (cf. Lopes 1987).

presentation of the frequencies of occurrence of a risky event (Fagerlin, Zikmund-Fisher and Ubel, 2011). To the best of our knowledge, Lopes and Casey (1986) are among the first who empirically studied distribution-like frequencies of risk representations ('risk as a function of shape') as an alternative to two-outcome gambles (see Figure 1). The main contribution of the Distribution Builder is the implementation of these ideas within a sound behavioral financial economics framework (e.g. modern portfolio theory and rank-dependent utility theory) and in a user-friendly online environment, thus making it attractive for widespread adoption by scholars and practitioners.

The Distribution Builder combines several decision variables interactively in a single tool, providing consumers with a simple and intuitive device to express their preferences over a large range of values of the decision variables used. In an investment context, consumers using the Distribution Builder are typically asked to determine their most preferred probability distribution for obtaining future income, given a budget constraint on the investments that they can make. In other words, with the Distribution Builder, consumers make joint decisions on risk and returns of financial outcomes, subject to budget constraints.
In Figure 2, we present the initial layout of the Distribution Builder as seen by users on a computer screen, and we highlight and explain in detail six important features of the measurement tool that enable the reader to better follow our illustrative examples and later sections. Figure 3 presents illustrative examples of the use of the Distribution Builder and of its main features.

At its most basic level, the Distribution Builder presents consumers with an interactive graph of 100 markers representing investment outcomes that occur with equal probability (see 'Features 1 and 2' in Figure 2), similar to tickets that are drawn in a

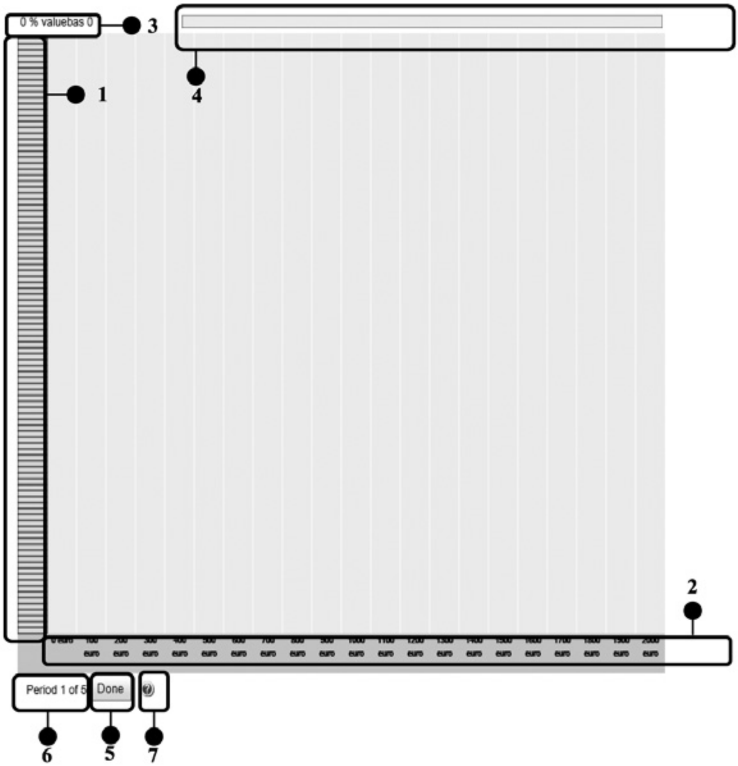


Figure 2. The Distribution Builder: initial interface layout

Feature 1. One hundred 1-percent probability markers situated in the leftmost column at the start. **Feature 2.** Outcome levels and labels corresponding to just as many discrete outcome columns, which any number of probability markers (individually or stacked) can be dragged-and-dropped to with a computer mouse. In the present setting, there are 21 outcome levels, from zero to 2,000 euros, in increasing order from left to right and in equal steps of 100 euros. **Feature 3.** Interactive investment budget meter, set to zero value (0%) at the start. **Feature 4.** Interactive investment budget meter bar. This is colored gray at the start, corresponding to no investment budget spent; all markers are then situated in their starting position in the leftmost column. The bar changes color depending on the percentage of investment budget spent, which in turn depends on the outcome distribution being constructed by moving the markers to the outcome levels. The differently colored bar moves to the right (left) indicating an increase (decrease) in investment budget spent. When the investment budget is underused (overused), the budget meter bar will be blue (red); see Figure 2 (panels B and C). When at least 99% of the investment budget is spent, the budget meter bar will be green (see Figure 2, panel D). The "Done" button can then be clicked to submit the outcome distribution constructed (see next feature). **Feature 5.** Users must click the rectangle-shaped "Done" button upon completion of (and when satisfied with) their most preferred outcome distribution. If the button is clicked when the investment budget is over- or underused, an automatic message will be displayed on screen, informing users to use 99% to 100% of the investment budget. **Feature 6.** Period counter to identify the period or round that a user is in. Users can use the Distribution Builder from 1 to the maximum number of rounds. **Feature 7.** Circle-shaped question mark help button. When clicked, an automatic message will be displayed explaining what the user must do (e.g. move the markers and respect the budget meter

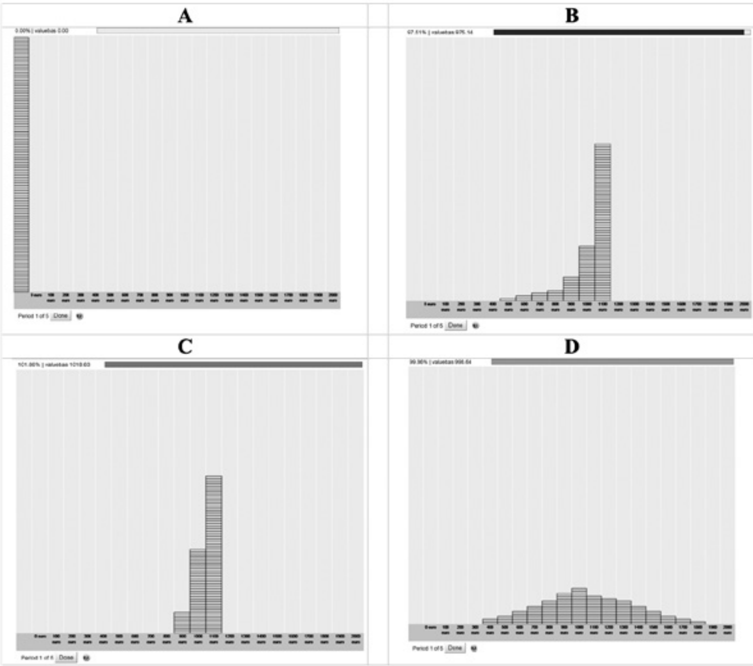


Figure 3. Examples of constructed outcome distributions in the Distribution Builder

Panel A. Initial Distribution Builder layout as seen by users on a computer screen (same as Figure 1). From here, users can drag-and-drop the green probability markers with a computer mouse into any preferred outcome distribution, provided they respect the budget meter. Panels B to D are examples of such outcome distributions. **Panel B.** An outcome distribution using less than 99% of the investment budget (hence the budget meter is blue). **Panel C.** An outcome distribution using more than 100% of the investment budget (hence the budget meter is red). **Panel D.** An outcome distribution using between 99% and 100% of the investment budget (hence the budget meter is green).

lottery. In addition, the Distribution Builder graphically represents the fact that (1) not all investment outcomes have equal value, (2) an individual's investments have to be made from a limited financial budget, (3) higher investment outcomes are more costly, and (4) by taking more risk a higher expected return can be obtained (This fourth aspect is implemented using unequal Arrow–Debreu state prices for each of the markers (Arrow 1964, Debreu 1959); more details are given below.)

When using the Distribution Builder, these four aspects are experienced through two key interface features. First, potential outcomes are ordered from low to high in the graphical interface. Second, consumers are presented with an interactive budget 'meter' that shows how much of their investment budget is spent depending on the potential outcome levels where they place the markers (see 'Features 3 and 4' in Figure 2). Thus, consumers cannot simply place all investment markers on the investment outcome that they prefer the most (i.e. the highest return). Instead, consumers are required to make tradeoffs between a fairly safe but average payoff and the chance of a higher payoff in combination with the chance of a lower payoff (see Figure 4; Panels B to D). This latter downside risk cannot be avoided – the chance of winning a relatively high amount of money is more expensive – so that expenditures for other markers will need to go down. The Distribution Builder interface furthermore assists consumers in the graphical interface by automatically assigning the underlying stochastic or probabilistic 'states' of the world (e.g. degrees of economic recession) and the corresponding state prices across the different outcomes, such that the budget required to achieve a specific distribution realization is minimized. In particular, the Distribution Builder interface automatically assigns higher state prices to markers with lower outcome levels (and vice versa), so that the rank order of the state prices for each marker is opposite to that of the corresponding outcome levels.[2] The intuition of this optimization routine is that achieving a certain payoff per euro invested in a more favorable state of the world (high asset returns) is less expensive than guaranteeing the same payoff in a less favorable state of the world (low asset returns). Thus, it is most profitable to assign favorable 'state of the world' conditions with corresponding low state prices to high payoff outcomes. The implementation of these tradeoffs and sound financial economics principles in an interactive graphical presentation of the frequencies of occurrence of a risky event are illustrated in the Distribution Builder examples in Figure 4.[3]

The benefit to consumers of integrating these different aspects of the investment decision in the Distribution Builder is that they gain access to a simple tool to solve a very complex task. In fact, Donkers et al. (2013) find that Distribution Builder 'ease of use' is significantly greater than a two-outcome lottery implementation. Furthermore, individuals are capable of correctly answering a set of questions before using the Distribution Builder and after listening to instructions on its use (see Figure 5). The structure of the underlying decision problem is such that the observed configuration of markers preferred by the consumer is driven by the trade-offs between expected mean investment outcome and investment outcome variance. This structure directly reflects the investment risk preferences of the individual, thus providing

2 States of the world are stochastic, i.e. uncertain. Uncertainty vanishes when a particular realization from the set of possible states of the world occurs.

3 A video used in Donkers et al. (2013) in their investment decision studies that illustrates and gives instructions to participants on how the Distribution Builder works is available at *http://www.marketingaterasmus.eu/stablelinks/DB_instr_video_October_2012.mpg*.

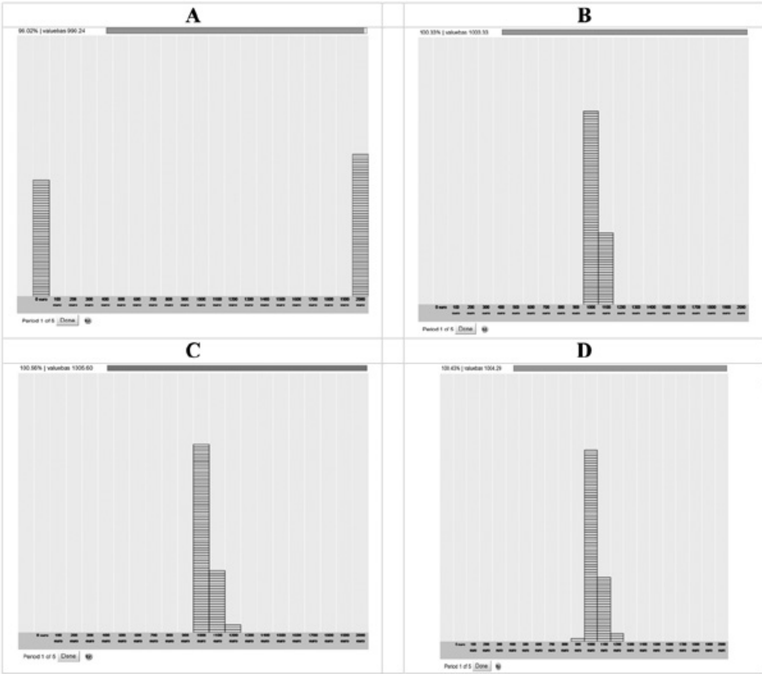


Figure 4. Example of the risk-return tradeoff and underlying state prices in the Distribution Builder

Panel A. An outcome distribution using between 99% and 100% of the investment budget (hence the green budget meter), where all probability markers are placed on two outcomes only (zero and 2,000 euros). With an investment budget of 1,000 euros, such preferred outcome distribution could indicate a risk-seeking individual. **Panel B.** An outcome distribution using between 99% and 100% of the investment budget (hence the green budget meter), where all probability markers are placed on two outcomes only (1,000 and 1,100 euros). With an investment budget of 1,000 euros, such preferred outcome distribution could indicate a risk-averse individual. **Panels C and D.** Starting from the outcome distribution of Panel B, moving three markers to the right to have a 3% chance of a return of 1,200 euros would mean spending more than 100% of the investment budget, which is not feasible (in Panel C the budget meter is red). To stay on budget, one must trade the chance of a 1,200 euro return for the chance of a lower return. Moving one marker from the 1,000 euros pile to the left, to a 1% chance of a 900 euro return, would be a possibility (in Panel D the budget meter is green).

an important input for investment portfolio recommendations. Another important benefit of the Distribution Builder interface is the embedded interactivity. This interactivity can support consumers in constructing their preferences in case these are not yet fully established. For researchers and practitioners, the Distribution Builder is a powerful and practical tool to elicit the risk preferences of individuals.

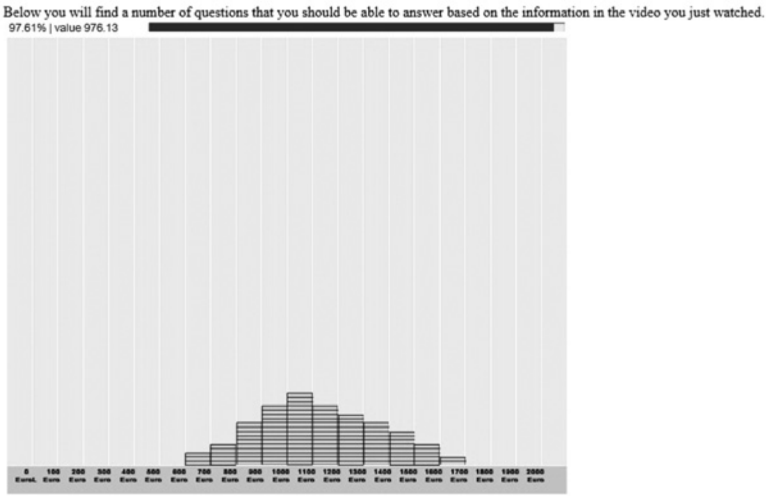


Figure 5. Outcome distribution in the Distribution Builder underlying the understanding questions to users

The understanding questions (and possible answers) used in Donkers et al. (2013) are the following: "Is the budget restriction respected by this distribution?" (*Yes* vs. *No*); "Compared to the probability of winning 1300 Euro, the probability of winning 1000 Euro is ..." (*Larger* vs. *Smaller*); "Which outcome level is most likely to occur?" (*2000 Euro* vs. *900 Euro*); "Is the chance of winning 1400 Euro or more smaller or larger than the chance of winning 900 Euro or less?" (*It is smaller* vs. *It is larger*).

2. Eliciting preferences from preferred outcome distributions

We now illustrate the use of preferred outcome distributions to elicit risk preferences in the context of rank-dependent preferences for decision-making under risk or uncertainty. The *economic* environment is captured in the Distribution Builder through the state prices, which describe the increase in expected payoff when one is willing to take more risk. A description of the construction of these state prices is deferred to the next section.

The basics

First, let us formalize the decision problem underlying preferred outcome distributions in case of rank-dependent preferences. Let $v(.)$ represent the value function and $\pi(.)$ the transformation that is applied to the cumulative probability distribution function (see Tversky and Kahneman 1992 and Quiggin 1981). Moreover, let $w=1,\ldots,W$ represent the possible states of the world such that they are ordered in terms of their state prices. In particular, with s_w representing the state price of state w, we assume $s_1<s_2<\ldots,<s_W$. Finally, p_w represents the probability of the state of the world w and o_w the desired outcome level for that state of the world. With B representing the available budget, a formal representation of the consumer's decision problem is then given by:

(1) $$\max_{o_w, w=1,\ldots,W} \sum_{w=1}^{W} \pi_w v(o_w), \text{ s.t. } \sum_{w=1}^{W} o_w s_w \leq B,$$

with

(2) $$\pi_w = \pi\left(\sum_{j=1}^{W} p_j\right) - \pi\left(\sum_{j=1}^{w-1} p_j\right).$$

Here π_w is the decision weight assigned to state w. If $\pi_w = p_w$, Equations (1) and (2) formalize the decision problem under expected utility, as in Goldstein et al. (2008). Note that the above specification represents rank-dependent preferences only if the states of the world, $w=1,\dots,W$, which are ordered in terms of ascending state prices by definition, are also ordered in terms of descending outcomes.

We will now show that for a preferred outcome distribution, i.e. a distribution that solves the decision problem in Equations (1) and (2), the outcomes are assigned in ascending order to states with state prices in descending order. Recall that there is a simple underlying intuition: guaranteeing a payoff in a more favorable state of the world (high asset returns and a low state price) is cheaper than guaranteeing the same payoff in a less favorable state of the world (low asset returns and a high state price). To show this intuition more formally, we first assume that the value function does not depend on the state of the world directly, but only on the outcome obtained in that state of the world. Second, we assume that the value function strictly increases, so that a larger budget will result in a higher utility. An optimal assignment of outcomes to states is then an assignment that has the lowest costs of obtaining that distribution. The lowest costs for a given distribution of outcomes are obtained by assigning the highest outcomes to the states with the lowest state prices. If this were not the case, reassigning the outcome levels would lower the required budget, making it possible to increase the outcome for at least one marker, which based on $v'(.)>0$ increases the (subjective) expected utility. This proves the suboptimal character of such an assignment.

To simplify the decision problem, the Distribution Builder makes efficient use of this link between the rank of the outcome of a marker in a preferred outcome distribution and the corresponding rank of its state price. Instead of a marker representing a particular state of the world, the tool identifies the state of the world that a marker corresponds to *ex post*, based on its position in the desired distribution. The state price for each marker (state of the world) is then only dependent on the marker's relative position in the outcome distribution, not on its absolute outcome level or on the specific marker. Individuals using the Distribution Builder need to think only about the shape of their preferred outcome distribution and not about the assignment of specific markers (states of the world) to specific outcome levels. This assignment is done in an optimal manner by the tool itself in the background and is only reflected indirectly to consumers through optimal use of the available budget.

Identification of preferences

In this section we distinguish between parametric estimation (which assumes particular functional forms of the functions of interest) and non-parametric estimation (which assumes no functional forms of the functions of interest) of risk preferences using data from the Distribution Builder.

The structure of the decision problem that underlies preferred outcome distributions facilitates the estimation of underlying risk preferences. The main idea is to use the first order conditions corresponding to the decision problem in (1) and (2). With γ denoting the Lagrange multiplier of the constrained optimization problem, the first order conditions with respect to the decision variables o_w are:

(3) $\pi_w v'(o_w) - \gamma s_w = 0$, for $w=1,\dots,W$.

Therefore, one preferred outcome distribution provides W observations on the value function and on the probability weighting function, allowing parametric versions of $\pi(.)$ and $v(.)$ to be estimated as long as markers (i.e. desired payoffs) are sufficiently spread over the range of outcome levels.[4] In case of constant relative risk aversion (CRRA) utility, Equation (3) simplifies further into:

(4) $ln(s_w) = -ln(\gamma) + ln(\pi_w) + \alpha ln(o_w)$, for $w=1,\ldots,W,$

which can be used for estimation of $\pi(.)$ and $v(.)$ using suitable functional forms for $\pi(.)$. Assuming expected utility, thus $\pi_w = p_w = 0.01$ in the case of 100 markers, the coefficient of relative risk aversion, α, can be estimated using linear regression, as in Goldstein et al. (2008).

While (3) provides enough information to enable parametric identification, non-parametric identification of $\pi(.)$ and $v(.)$ with W decision weights π_w requires more than W observations. One solution is to elicit preferred outcome distributions in multiple scenarios (at least two) that vary in state prices s_w (and hence average returns) and perform the estimation combining the resulting information in the various preferred outcome distributions.[5]

Take the simplest case, of two preferred outcome distributions, one with high average returns and one with low average returns, denoted by H and L, respectively. The first order conditions are represented by:

4 This may not always be the case. For example, Goldstein et al. (2008) exclude 50 out of 620 observations, as those observations have all markers at the reference level. A Bayesian estimation method aggregating parameter information across individuals could solve this identification problem.

5 Another option is to combine information of at least two preferred outcome distributions with different investment budgets.

(5) $\pi_w v'(o_w^c) - \gamma^c s_w^c = 0$ for $c = H,L$ and $w = 1,\ldots,W$.

Combining the first order conditions for the w^{th} marker in the two scenarios provides the following equation that can be used straightforwardly to estimate the *value function*:

$$(6)\quad \frac{v'(o_w^H)}{v'(o_w^L)} = \frac{\gamma^H s_w^H}{\gamma^L s_w^L}\ .$$

In Equation (6), the probability weights have cancelled out, facilitating estimation of the value function. Then taking logarithms, we obtain

$$(7)\quad ln(s_w^H) - ln(s_w^L) = ln(v'(o_w^H)) - ln(v'(o_w^L)) - ln(\gamma^H) + ln(\gamma^L).$$

Similarly to Equation (4) above, $v'(o_w)$ in Equation (7) can be estimated using linear regression. Having estimates of $v'(o_w)$ for all relevant outcome levels, identification of π_w is straightforward. Specifically, with $\pi_w = \gamma^c s_w^c / v'(o_w^c)$ from Equation (5), with s_w^c known, an estimate of $v'(o_w^c)$ available, and using $\sum \pi_w = 1$, we find $\gamma^c = 1 / \sum(s_w^c / v'(o_w^c))$ and hence identify π_w for each scenario. Having established identification, the analysis can also be based on log-linearized versions of the original first order conditions in Equation (5) and use of a linear regression model:

$$(8)\quad ln(s_w^c) = ln(\pi_w) + ln(v'(o_w^c)) - ln(\gamma^c)\ ,$$

for $c = H,L$ and $w = 1,\ldots,W$,

enabling estimation of $ln(v'(0_w))$ and $ln(\pi_w)$ jointly, based on the information contained in the two preferred outcome distributions.

3. Constructing state prices

For the construction of state prices we follow Sharpe et al. (2000) and Sharpe (2001). The reader is referred to those works for an extensive motivation and more detailed exposition of the approach. Doing so, we assume a world with only one risky asset and a risk-free asset, so the wealth level in the economy – and hence the state price – is determined by the payoff of the risky asset. To obtain 100 states of the world, the 0.005, 0.015, ..., 0.995 percentiles can be selected from a log-normal distribution with parameters that correspond to the returns of the risky asset identified above. For the corresponding state prices we can rely on a specification that is log-linear in prices and in wealth level in each state of the world.[6] In particular, one can assume $ln(s_w) = \alpha + \beta ln(W_w)$ (or, equivalently, $s_w = exp(\alpha)(W_w)^{\beta}$). In addition, the state prices need to satisfy two restrictions, namely: (1) an investment with one unit payoff in every state of the world costs $\frac{1}{1+r^f}$, with r^f denoting the risk-free rate, hence $\Sigma s_w = \frac{1}{1+r^f}$; (2) one unit investment in the stock should cost its risk-discounted present value, hence $\sum s_w W_w = 1$. From each of these restrictions we get $exp(\alpha)\Sigma(W_w)^{\beta} = \frac{1}{1+r^f}$ and $exp(\alpha)\Sigma(W_w)^{\beta+1} = 1$, respectively. These equations can be combined into a single equation with one unknown, β, which is solved numerically. Substituting β back into one of the two restrictions yields α.

6 The actual set-up of state prices defines the expected return on risky assets (stocks), the standard deviation of the risky return, and the risk-free rate (and hence an equity premium).

A key feature of the resulting state prices is that there will be more variation in the state prices in the high return scenario, while the average state price equals 1/(1+r) in any scenario, since a safe investment that pays off one in every possible state of the world costs 1/(1+r). In particular, in the high returns scenario, the state prices for the bad states of the world are higher, and so $ln(s_w^H) - ln(s_w^L) > 0$. Assuming risk aversion, i.e. a decreasing v', and ignoring the intercept in Equation (8), it is optimal to put markers corresponding to those states at lower values in the high return scenario, since $o_w^H < o_w^L$ implies $v'(o_w^H) > v'(o_w^L)$. The opposite holds for markers corresponding to good states of the world, and therefore $ln(s_w^H) - ln(s_w^L) < 0$. Hence, compared to the low returns scenario, it is optimal to assign a marker for a good state of the world to a higher outcome (i.e. an outcome where marginal utility is lower) when returns are high. As a result, consumers' preferred outcome distributions in a high returns scenario are expected to be more dispersed than in a low returns scenario. Indeed, as one would expect, optimal risk taking is higher when the returns from risk taking are also higher.

4. Choice architecture and design implementation

Decisions under uncertainty and the choices consumers make (which are the basis of revealed preferences) are influenced by not only by individual characteristics and factors that may change over time, but also by the 'choice architecture.' In this section we introduce design choices closely related to choice architecture as described by Thaler and Sunstein (2008). Specifically, subtle aspects such as reference points presented in the interface, ranges of investment values, changes in investment budget, and the language terminology used in the Distribution Builder can all have strong impact on consumer pension investment decisions.

Furthermore, a choice architecture can be specified by parameters spanning from the decision context (saving for retirement, health treatments, new product purchases, playing sports outside on a rainy day) or the set of alternatives available (two or more alternatives and which ones) to parameters such as the framing of risks (as gains vs. losses), the operationalization of risks (as single event probabilities, as frequency statements, within a reference class), or even the presentation format of risk, all of which can have dramatic consequences for consumer choice.[7]

Graphical presentation format

Message framing and message presentation effects are well known in consumer, medical, and auditor judgments (Sen 1998,

7 Another important parameter is that of experience. This is increasingly important with online technological interfaces that allow interactivity between the decision maker and the object of choice. Given its importance, we discuss this category separately below, as it introduces specific cognitive mechanisms intervening in the decision process such as consumer learning (about risks and risk presentation formats).

Levin, Schnittjer, and Thee 1988, O'Clock and Devine 1995), as well as in gambling (Erev and Cohen 1990). Taken together, these streams of research have demonstrated over the past two decades that the principle of preference invariance underlying expected utility theory is frequently violated and that normatively equivalent presentation formats affect choices (Kahneman and Tversky 2000, Soman 2004; cf. Nenkov, Inman, Hulland, and Morrin 2009).

Few studies, however, have investigated the effects of information formats and presentation biases in an investment decision-making context. Nenkov, Inman, Hulland, and Morrin (2009) studied presentation formats (e.g. the use of the so-called Morningstar Style Boxes, which describe investments) and their interaction with personality traits (propensity to elaborate outcomes), while Rubaltelli, Rubichi, Savadori, Tadeschi, and Ferreti (2005) have shown that the status quo bias in investment decisions is affected by the format used to present investment returns (frequencies vs. percentages). Similarly, Gottlieb, Weiss, and Chapman (2007) concluded that the extent of some biases (the common-ratio effect and the common-consequence effect) depends on whether uncertainty is presented as percentages or as frequencies.

Only recently have there been studies that devote attention to presentation formats aimed at reducing decision biases and/or interactive formats, now widely available as decision support systems in an online context (see Haubl and Trifts 2000 for an example in the marketing science literature).[8] Hutchinson, Alba, and Eisenstein (2010) documented the dependency of

8 Benbasat and Dexter's (1985) is one of the few early studies that examined the effects of the design of decision support systems – graphics and color – on management decisions, specifically budget allocations.

format presentation on managers' educated decisions (budget allocations), leading to biases that are not reduced by any specific format or training. In the context of savings for retirement, Hershfield, Goldstein, Sharpe, Fox, Yeykellis, Carstensen, and Bailenson (2011) developed an interactive tool that helps consumers connect with their 'future selves' and hence improve their savings decisions. The medical literature, however, is perhaps the most advanced at the moment when it comes to understanding the effects of graphical presentation formats on risk perceptions.[9] Similar to a savings-for-retirement context, where individuals make tradeoffs between current and future wealth, individuals in a medical context often have to make decisions that imply tradeoffs between current and future health. In both contexts, uncertainty or risk must be factored in.

Increasing evidence from medical studies shows consistent effects of interactive graphical displays on risk perceptions and improved decisions under uncertainty (see e.g. Ancker, Weber, and Kukafka 2011, Wallace, Leask, and Trevena 2005, Gigerenzer and Galesic 2012, Fagerlin, Zikmund-Fisher, and Ubel 2011, Waldron et al. 2011, Ahmed et al. 2012, Elwyn et al. 2006), and in general this evidence points to the superiority of frequency formats as representations of risk and decision tool's interactivity as effective means of experience of uncertainty (as probabilities) for decision makers. These aspects are taken up by the Distribution Builder graph, the implementation of which depends on choices made regarding its decision variables.

9 The only study in economics literature dealing explicitly with graphical interfaces that we are aware of is that of Choi, Fisman, Gale, and Kariv (2007).

Decision variables and detailing the Distribution Builder graph
In its basic form, a Distribution Builder is suitable for tasks in which consumers are asked to invest a fixed amount of money over a fixed period of time (e.g., a 10,000 euro investment for 5 years), with the key aspect of choice being the risk-return tradeoff. The Distribution Builder has been used in other domains too and has thus used other decision variables. Ordabayeva, Goldstein, and Chandon (2010), for instance, have used the Distribution Builder interface to study actual versus perceived income distributions among North-American consumers. In a context of pension investments, several other decision aspects may be relevant, such as choosing to invest more versus less or to retire earlier versus later in life. As shown by the recent example of PGGM's online "pension explorer" in the Netherlands (see *http://www.pggm-pensioenverkenner.nl/* and Verbaal (2011)), these decisions aspects can also be built into an interactive consumer interface.

To implement this choice architecture, the researcher chooses the investment context (e.g. financial gambles, saving for retirement), the amount available for investment or investment budget, the range and level of discreteness of possible outcomes (e.g. 21 outcomes, from 0 to 20,000 euros, in steps of 1,000 euros), and the investment scenario determining prices (e.g. higher average returns vs. lower average returns). Other decision aspects in the Distribution Builder may be relevant as well. For instance, in the Distribution Builder it is possible to choose the number of markers, that is, the minimum probability that consumers will face. In general it is easier for subjects to think of probabilities in the 0 – 100 space, and therefore one hundred markers are a natural choice that benefits from the frequent use of percentages in everyday transactions (see Feature 1 in Figure 2).

In the context of pension investments, it may also be desirable to signal a reference point.[10] This is the case of highlighting in the Distribution Builder environment what percentage of pre-retirement income a consumer needs in order to maintain a spending pattern that is similar to that allowed by an average income throughout the consumer's active employment period.

These elements allow Distribution Builder users to reveal their preferred outcome distributions, which taken together essentially make up for discrete probability distributions constructed under an underlying cost and a limited investment budget.

Consumer Interaction

One particularly important aspect of the Distribution Builder is that it allows users to learn about risk by engaging in repeated trials.[11] When a consumer assigns all markers to outcomes and submits a distribution, one of the markers is drawn at random, allowing the user to 'experience' the outcome of an investment. While interacting with the Distribution Builder, the consumer is thus directly confronted with (experiences, in other words) the inherent trade-off between taking a greater risk and the possibility of obtaining a higher expected investment outcome (see Figure 6).

Research in psychology and decision-making has long underscored the virtues of experiencing the outcomes of

10 To properly establish the income level that will provide a standard of living that is comparable to one's current living standard may be as important as determining the desired tradeoff between risk and returns. This, however, is outside the scope of this design paper.

11 Direct experience may also take place during training rounds to ensure that users understand the Distribution Builder before the actual experimental task at hand. Indirect experience may be acquired from supporting devices to ensure understanding of the Distribution Builder, with videos being very effective in an online environment.

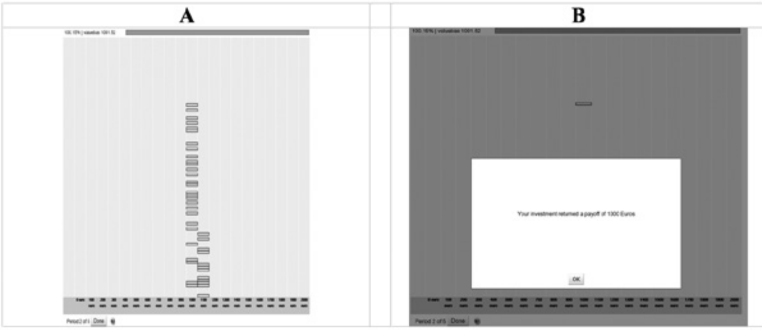


Figure 6. Experiencing probabilities and outcomes in the Distribution Builder

Panel A. Upon constructing a preferred outcome distribution and clicking the "Done" button, the Distribution Builder randomly fades out all the markers but one, corresponding to the final outcome faced by the individual. **Panel B.** The flashing of the last marker is followed immediately by an automatic pop-up message to the user stating the value of the materialized outcome; in this case "Your investment returned a payoff of 1,000 euros."

stochastic processes when training individuals in statistics. Mixed findings challenge the idea that personal reasoning follows the formal postulates of statistics, and simple training and education tools such as the Galton Board or Quincunx have long been used to teach students the principles of probability (Sedlmeier and Gigerenzer 1997, 2001). Estes (1976) developed an "observation-transfer paradigm" based on categorical memory (distinguished from episodic memory), a paradigm within which probability learning and transfer derive from frequency learning.[12]

In a seminal experimental study on descriptive-based versus experienced-based decision-making (DBDM vs. EBDM), Hertwig,

12 See the references above in the medical literature for a set of recent studies emphasizing the role of a 'reference class' for successful risk communication with patients.

Barron, Weber, and Erev (2004) documented a preference reversal linked to the mode in which probabilities were presented (see also Baron and Erev 2003, Jessup, Bishara, and Busemeyer 2008). When faced with two options with the same expected value – a sure option versus a risky option, with one of the outcomes associated with low probability – the majority of participants preferred the risk-free option when probabilities were described rather than experienced and the risky option when probabilities were experienced rather than described.

This evidence of a preference reversal and the implicit result that individuals tend to underweight small probabilities when risks are experienced, at odds with the overweighting of small probabilities in prospect theory, was confirmed in recent work on the economics of decision-making under uncertainty (Abdellaoui, L'Haridon and Paraschiv 2011), but only in the domain of gains (not losses).[13] Still, it is not clear whether this new result challenging the inverse S-shape of probability weighting function of individuals is due to an experience of outcomes per se, or a result of sequential sampling and thus learning, or both (see e.g. Fox and Hadar 2006, Hau, Pleskac, Kiefer, and Hertwig 2008, Hadar and Fox 2009, Rakow, Demes, Newell 2008, and Rakow and Newell 2010).

An important consideration in constructing and using the Distribution Builder is the need to lead individuals through

13 Implicitly, these findings highlight the importance of focusing not only on probabilities, as is typically done under the two most common risk preference elicitation methods (Holt and Laury 2002 and the trade-off method of Wakker and Daneffe 1996), but on both probabilities and outcomes. As pointed out by Donkers, Lourenço, and Dellaert (2012), however, experimental research methods in the economics of decision-making under uncertainty rely heavily on sequences of choices over gambles that are time-consuming and cumbersome, difficult for individuals to negotiate, and subject to drawbacks such as error propagation (see Harrison and Rutstrom 2008).

training rounds to learn how to use the tool (see Feature 6 in Figure 2), which as a by-product may lead to some debiasing. Future research should therefore explore the data from training sessions with the Distribution Builder. That can shed light on existing learning patterns and answer important questions such as the extent of learning and how it may vary with a different number of training rounds, and how learning relates to not only characteristics of consumers using the Distribution Builder, but also to the elements of the tool itself.

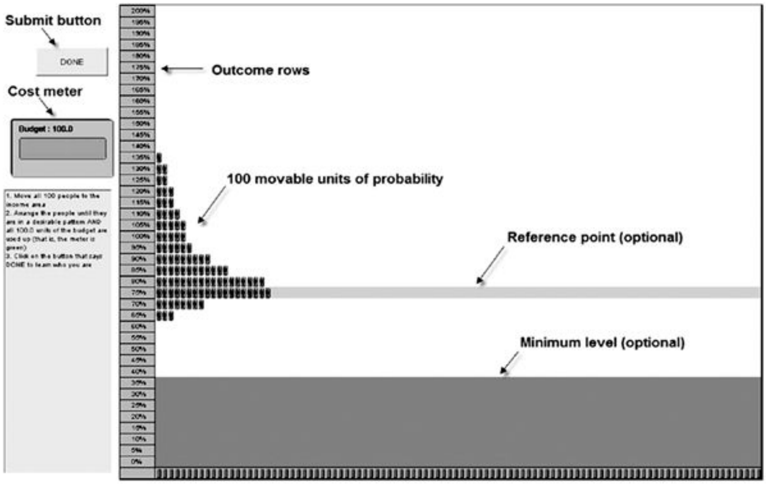
5. Uses of the Distribution Builder

The Distribution Builder in pension decision-making

One challenge for developers of a Distribution Builder in the context of the pension decision-making process is to ensure that it is designed in such a way that it can reflect consumers' risk preferences for the *key outcome* of interest. In case of pension products, this is the risk associated with the consumer's income level at retirement (Dellaert and Turlings 2011). It is particularly challenging to design and communicate a measurement approach to pension risk that incorporates all relevant decisions that affect the consumer's income at retirement. Typically – in practice as well as in academic theory – only a limited relatively well-defined set of lotteries or at best investment outcomes are evaluated in risk-attitude measurement tasks. A first successful attempt using the Distribution Builder in a savings-for-retirement decision context is that of Goldstein et al. (2008), who studied U.S. citizens who had been saving for retirement for 5–30 years; the Distribution Builder interface that was used in that study is presented in Figure 7.

For a Distribution Builder to realistically capture the most important aspects of consumer decisions regarding retirement saving and retirement timing, the interactive graphical tool has to be expanded beyond its current design. In this respect the following key features come to mind:

- Retirement date
- Monthly premium to be paid
- Monthly retirement income
- Uncertainty about state pensions



NOTE.—Using movable units of probability, participants can create arbitrarily shaped discrete probability distributions over numerous outcomes (on the vertical axis). Between two and 40 outcomes and one and 100 units of probability can easily be displayed on a standard-size monitor. The 40-outcome/100-unit case provides over 10^{34} unique distributions to choose among. A cost meter (upper left) can be used to constrict the space of allowable distributions, for example, to those that have a particular risk-return relationship. The cost meter functions by not allowing one to submit a distribution (using the submit button on the upper left) until it satisfies an arbitrary cost function. Users can see how every change to the distribution affects the cost meter numerically and graphically. All movements are seen in the context of their effects on the system as a whole. Color version and video demonstration available as online enhancements.

Figure 7. The Distribution Builder interface in a savings for retirement decision context

The above is Figure 1 in Goldstein et al. (2008). Note the two shaded areas: the reference point (75% of pre-retirement income) and the minimum level (35% of pre-retirement income).

Retirement date. The desired retirement date is an important driver of pension wealth and pension wealth needs. By making the retirement date dependent on investment returns, however, it can also be used as a mechanism to reduce pension income risk. For example, one can imagine a person being willing to accept a 25% risk of retirement one year later, thereby offsetting all or part of the investment losses incurred in the worst possible investment scenarios. Inputs to the Distribution Builder should therefore include the desired retirement date and the consumer's willingness to work longer in case of low pension wealth levels.

Monthly premium to be paid. In the basic Distribution Builder, consumers can use up a certain budget to obtain their preferred outcome distribution, subject to the budget constraint. In a pension income Distribution Builder, one can take the monthly premium as a given, resulting in a budget constraint that has to be satisfied.[14] It may be more insightful for consumers to see how monthly pension premiums change when the desired pension income distribution and retirement age are changed. A detailed simulation model is required in the background to perform the computations needed to generate these insights.

Monthly pension income. This will always be the key decision variable for which consumers can select the desired outcome distribution. Since income levels are linked to varying levels of social status and/or activities, it may be helpful to make the level of feasibility of such activities visible in the interface. For example, one could color-code the outcome levels to indicate whether the consumer has sufficient resources to continue living in his current home or, more generally, to maintain his current standard of living.

Uncertainty about pensions. Population aging puts growing pressure on the value of pensions. Before incorporating an important feature such as the degree of uncertainty in a pension, it would be useful to examine whether people are capable of creating *realistic* beliefs about the range and uncertainty of their state pensions. If they cannot, the uncertainty can still be

14 This budget constraint is not the same as in the regular Distribution Builder, as the final pension income distribution will be restricted by the premiums that are paid.

included through scenarios designed by the developers of the graphical tool.

One final challenge will be to periodically update the risk attitude measures and pension product advice of individual consumers in order to account for factors such as shifts in expected income level or variations in budget allocation (e.g. buying a new home) that may affect an individual's reference points, or shifts in the person's investment portfolio.

The next step in assessing the benefits of the Distribution Builder is to transform this tool to the pension context along the lines suggested above. The tool is capable of integrating all aspects of the pension decision-making process and the corresponding outcomes into a single decision support tool that is highly relevant for defined contribution pensions. In The Netherlands, where defined benefit schemes are most common, the Distribution Builder has generated enthusiasm among pension fund administrators, including a number of Netspar partners, as the tool can also be used to communicate the risks and the impact of retirement age on pension income.

Distribution Builder-based advice

Regardless of whether improved understanding of probabilities results from concrete training or from spontaneous learning, the use of tools such as the Distribution Builder serves to *debias* existing perceptual errors in the encoding and use of probabilities. When it comes to providing investment advice, it is thus important to know whether consumer decisions in the Distribution Builder should be debiased to bring them in line with normative recommendations when making investment decisions. This applies particularly to potential biases in risk perception, as well as to potential biases associated with loss aversion. If advice is provided based on choices made using the Distribution Builder, it is important to know which and how many investment portfolios can be offered to consumers as realistic alternatives in the context of pension investments.[15] Moreover, it is common practice among financial advisors to characterize structured products by payoff functions (Figure 2) that only illustrate the magnitude of potential payoffs, without any information as to the probability of this occurrence (Wallmeier 2011).[16]

Two related main questions regarding the provision of investment advice in the context of risk preferences constructed with the Distribution Builder are: (a) in which format can such advice be presented (specifically, how can advice be provided with the Distribution Builder, whether using the same layout as the Distribution Builder itself and/or presenting an investment portfolio that matches consumer preferences in a Distribution Builder format), and (b) whether such advice should be debiased.[17]

As mentioned above, several studies have investigated whether investment choices improve with different ways of communicating underlying probability distributions (see e.g. Barron and Erev 2003, Hertwig et al. 2004, and Hau et al. 2008), in particular

15 Deviations from objective risk measures and probability biases are observed among financial advisors too. Regarding myopic loss aversion, for instance, not only was the behavior of advisors affected by the bias, but its bias was even stronger than that of students in a control group (Eriksen and Kvaloy 2010).

16 Sophisticated investors, financial advisors, and portfolio managers are *supposed to* be familiar with the counter-intuitive idea to many investors that under rational expectations stock prices behave like a random walk in an information-efficient market (Louis Bachelier in 1900, later formalized by Fama 1970). It is the random walk argument that allows comparing investment products to lotteries, an analogy that makes sense because the investor faces some inherent risk.

17 Whether consumers accept or debias investment advice and which factors determine acceptance are different questions. For an extensive review of investment advice acceptance see Donkers et al. (2012).

mere description, graphical presentation, or experienced through sampling, features all present in the Distribution Builder. For instance, analyses of myopic loss aversion (i.e. aversion to short-term losses despite a long-term investment horizon) show that providing subjects with an explicit distribution of potential outcomes can overcome aversion to short-term losses (Benartzi and Thaler 1999) and that "computing, showing and discussing" probability distributions may avoid utility losses in asset allocation decisions (Klos et al. 2005). Despite accumulated evidence from the experimental literature supporting communication of return distributions based on investment horizon instead of shorter periods, few studies have considered the asset allocation between stocks and bonds (an exception being Haisley et al. 2010). Thus, little is known about how best to communicate investments in derivatives or structured products.

For most structured products, an experience-based communication environment is challenging. Consider, for example, the huge number of draws that would be necessary to obtain a useful estimate of the probability of hitting the downside barrier of reverse convertible securities. Recognizing this challenge, Wallmeier (2011) proposes several presentation formats for risk-and-return communication in portfolio management: return histograms and bar charts of ordered returns, and the rolling dice analogy to present return distributions in addition to payoff profiles. A description of presentation formats is included in Appendix A.

The features of return histograms and bar charts of ordered returns that are desirable for effective risk communication and the steps to build them are somewhat similar to those of the Distribution Builder, and they involve constructing a probability density function derived by historical simulation or Monte

Carlo simulation (Wallmeier 2011).[18] Other risk measures such as value-at-risk and higher moments of the return distribution (skewness and kurtosis) can be included in histogram-like presentation formats. Similar to the return dice presentation and the return histograms, the Distribution Builder offers a balanced view because it reveals that a high return can be realized only if the investor is willing to accept an equally high risk of loss, thus neutralizing the tendency of investors to focus on a maximal return.[19]

Normatively, individuals should recognize the superior value of a debiased distribution. Therefore, they should always choose the debiased advice alternative, regardless of the scenario they are in (e.g. three experimental conditions: (a) bias is not communicated, (b) bias is communicated without explanation, and (c) bias is communicated with explanation). Within this perspective, any additional information is redundant or reassuring at best. Departures from full acceptance of advice, however, can be expected, and there will be differences in advice acceptance rates across different scenarios (see Donkers et al. 2012 for more details on predicting acceptance of investment advice).

18 In the Distribution Builder only state prices are required as inputs, and one can choose either historical simulation or Monte Carlo simulation to compute them. Given the simple analytical solution available for log normally distributed payoffs (Sharpe 2000), our research builds on analytical specifications of the return process.

19 The suggestion given by (Wallmeier 2011) of how "a financial advisor could explain the dice analogy to a client," is rather amusing: "An investment in this product involves some market risk. This means that the return over a one-year period is uncertain. The reason is that we do not know in advance if new information coming to the market in the future will be favorable or unfavorable for the asset. To get a better feeling of the risk involved, the following analogy might be helpful: the risk can be compared to rolling a dice where higher returns are paid out when the dice shows a higher number".

Conclusion

This paper has offered both an intuitive and a more technical overview of the basic structure of the Distribution Builder as a tool to support financial investment and pension decisions. We have discussed the relationships between outcomes, uncertainty, and risk-return tradeoffs and how these concepts operate within the Distribution Builder. Particular attention has been given to different design decisions such as presentation formats and detailing options of the Distribution Builder graph and to their implications for user interaction. We have specifically highlighted the beneficial aspect of the Distribution Builder in that it allows consumers to virtually experience outcome probabilities. That makes this tool an effective means for improved understanding of risks compared to static, non-interactive descriptions of probabilities (as used in most academic studies to date). Finally, we have particularly addressed the potential use of the Distribution Builder in the domain of pension funds and savings for retirement, since we believe that it can be a valuable tool to enhance consumer understanding of risk-return trade-offs when making pension decisions. In future research it would be especially valuable to test real-world applications of the tool and thus evaluate its effectiveness in practical pension applications.

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Appendix A

In this appendix we summarize a number of return distribution presentation formats as presented in Wallmeier (2011).

First, a payoff diagram can be provided that links the payoff of a product to the price of the underlying asset.

Second, a return histogram often provides interesting information that is not contained in the payoff diagram. For example, the downside risk of a barrier-reverse convertible is clearly visible as a kind of counterbalance to the positive scenario of maximum return.

Third, a discretization of the return distribution into 50 equal parts can be made, where each part represents a probability of 2%. The expected return for each part can be computed, and these expected returns can be plotted in ascending order. This form of presentation is sometimes used to show the historical returns of an investment product (see Beshears et al. 2009). Its advantage is that each bar represents the same probability. Thus it is not necessary to think in terms of probabilities to interpret the graph. The range of possible returns is clearly visible, and the profiles meaningfully reflect the specific characteristics of different products.

Fourth, a dice representation also has equally likely outcomes, the main benefit being that people are more familiar with the probabilities of rolling a dice. The downside is that they all represent 16.7% probabilities; as such the risk representation might be too coarse to enable proper advice.

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Building a distribution builder

Recent research suggests that advice and communication about investment risks can be improved by use of the Distribution Builder (Goldstein, Johnson, and Sharpe 2008). Essentially, this is an interactive tool that allows consumers to engage in a hypothetical investment task and to experience risk-return tradeoffs. The objective of this paper by Bas Donkers (EUR), Carlos Lourenço (EUR), Daniel Goldstein (Microsoft Research and London Business School), and Benedict Dellaert (EUR) is to provide an overview of design considerations when developing a Distribution Builder that is intended to measure two main characteristics of the risk profile of consumers: the utility function (how outcomes are valued by consumers) and the probability weighting function (the extent to which consumer perceptions of probabilities are biased). The authors focus on the domain of financial investments, in particular those related to pension funds.